PELAGIC RESOURCES OF THE GULF AND GULF OF OMAN

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
UNITED NATIONS DEVELOPMENT PROGRAMME
Rome, 1981

TABLE OF CONTENTS

1. PREFACE AND GENERAL INTRODUCTION

1.1 PREFACE

This report is the result of the collective efforts of the following project biologists, acoustic expert and counterparts, who made field observations, data collection, analyses, and contributed individually and collectively to the preparation of the various sections of the report. Those sections and appendixes which were the main responsibility of individual scientists appear under their authorship.

Project Biologists and Acoustic Expert*

M. Lamboeuf	- R/V LEMURU, August 1977 - March 1978
W.J. Scheffers	- R/V MAJID, February 1978 - December 1978
E.J. Simmonds*	- R/V LEMURU, August 1977 - November 1978
J. Vidal-Jünemann	- R/V LEMURU, January 1977 - August 1977
	- R/V MAJID, November 1977 - December 1977
P. Walczak	- R/V LEMURU, February 1978
M. Yesaki	- R/V MAJID, August 1977 - October 1977 and January-February 1978
N.P. van Zalinge	- R/V LEMURU, April-May 1977

Counterparts

S. Al Alawi	- (Bahrain) analyses of water samples
H. Al Zayed	- (Bahrain) R/V LEMURU
T. Cheriyan	- (UAE) R/V MAJID
K.S. Farsi	- (Oman) R/V LEMURU
S.I. Marji	- (UAE) R/V MAJID
P.J. Thomas	- (UAE) R/V MAJID
G.A. Yassir	- (Iraq) R/V LEMURU

Masterfishermen B.J. Bjarnason (January-July 1977), J. Johannesson (August 1977 - April 1978) and T. Hinriksson (August 1978) made valuable contributions in the acoustic survey of the small pelagic resources by R/V LEMURU. Masterfisherman J. Wedderburn (January 1977 - December 1978) on R/V MAJID assisted in scouting for schools of small and large pelagics and was responsible for exploratory fishing with purse seine, gillnets and trolling lines.

The survey programme was supervised by M. Yesaki (November 1976 - December 1977) and K. Sivasubramaniam (January 1978 - July 1979). L.K. Boerema (then Senior Fishery Resources Officer, FAO Headquarters) provided advice and assistance during the survey period and in the preparation of the reports.

A significant contribution to the survey programme was made by the United Arab Emirates by providing the R/V MAJID. The cooperation of the national authorities in UAE and other member countries is noteworthy and gratefully acknowledged. R/V LEMURU, which carried out the acoustic survey, belonging to the FAO/UNDP Vessel Pool was managed and equipped by the Fleet Management Section.

1.2 GENERAL INTRODUCTION

The project area for the survey included the Gulf and Gulf of Oman bounded by eight countries which, in a clockwise order, are the Sultanate of Oman, United Arab Emirates, Qatar, Bahrain, Kingdom of Saudi Arabia, Kuwait, Iraq and Iran, and by the Arabian Sea at its eastern end. The marine environment has very special geographical and meteorological conditions, and therefore is not comparable to any other sea areas, except perhaps the Red Sea and the Gulf of Aden.

Traditional fisheries in almost all the countries bordering the project area exploited the demersal resources primarily and the pelagics only secondarily. Large pelagics such as sharks, and - in some cases - even tuna and tuna-like fishes, were not highly preferred as food fish. However, the following developments in the region have led to an increased exploitation of the pelagic resources: increasing demand for small pelagics from the fishmeal industry, for large pelagics such as tuna and tuna-like fishes from an established cannery and for pelagic sharks from sharkfin and shark leather exporters and shark liver oil producers in the region. However, due to insufficient information on these resources, developments in this sector have slowed down and in some instances the investments made proved to be non-profitable.

This situation resulted in the decision to undertake an evaluation of the pelagic stocks in the Gulf and Gulf of Oman, and consequently the Regional Fishery Survey and Development Project was given the task of carrying out an acoustic survey of the pelagic resources.

A working group of experts met in September 1975 to consider the most appropriate survey design and strategy, and recommended four acoustic coverages of the survey area (FAO, 1976). However, the unusual environmental conditions in the area and absence of background information on the pelagics for an acoustic survey compelled the project to carry out preliminary investigations with the acoustic equipment before major seasonal coverages could be attempted, and therefore only three seasonal coverages were possible within the remaining operational period. Further, the extent of the survey area was such that a timespan of not less than 2 1/2 months was necessary for each coverage, though a shorter period was desirable. Hence, the period of each coverage was chosen so as to represent a season with fairly uniform environmental conditions.

R/V LEMURU was assigned to carry out the acoustic survey and sampling to estimate the abundance of small pelagic species, and R/V MAJID to carry out scouting for pelagic schools and exploratory fishing for small and large pelagics using a sardine purse seine net, trolling lines and sonar. The results of the preliminary phase of the acoustic survey are presented in part 2, the major seasonal acoustic coverages in part 3, and information on large pelagics from R/V MAJID in part 5 of this report. The information on small pelagics collected by R/V MAJID are incorporated into the results of the major seasonal acoustic coverages.

During the preliminary phase of the acoustic survey, both the echo-integrator and sonar contact systems were used to estimate the abundance of small pelagics. However, due to various limitations arising from environmental factors and the absence of relevant background information on school sizes, the sonar contact system of estimating abundance was discontinued during the major seasonal acoustic coverages.

Toward the end of the survey period, information on the commercial scale purse seine operations for sardine off the west coast of UAE (Ras Al Khaimah Fishing Company) was kindly made available to the project. An analysis of the data revealed very valuable information on the resources and biology of the small pelagics and therefore these results are also presented in this report (part 4).

To supplement the information obtained from the surveys conducted, relevant information has also been extracted from the demersal survey results, observations on artisanal fishery in the project area, and the indicative fishing operations carried out by project vessels after the completion of the survey programme.

Such indicative fishing was recommended by the Second ad hoc Working Group, which met in Doha in April 1978: R/V LEMURU to carry out indicative fishing for small pelagics with commercial type purse seine net and midwater trawl, and R/V MAJID to carry out indicative fishing with purse seine drift net and trolling lines for large pelagics.

During the resources survey all participating vessels recorded water temperatures at the surface and at various depths, and also collected water samples which were analysed for salinity at the Laboratory of the Fisheries Resources Bureau in Bahrain. R/V LEMURU was the only vessel which covered the entire project area throughout three seasons and hence was able to carry out a systematic study of the environmental conditions. This formed the basis of the report on environmental conditions in the project area to be issued as
(FAO, in preparation).

1.3 RESEARCH VESSELS AND EQUIPMENT

1.3.1 R/V LEMURU

The ship used in the acoustic survey was the R/V LEMURU, chartered by the project from the FAO/UNDP Vessel Pool. This is a multipurpose research vessel with the following characteristics:

Year of construction	- 1967
Hull	- Steel
GRT	- 165.36 t
Overall length	- 29.35 m
Draught	- 2.5 m
Engine	- Caterpillar D379TA
Horsepower	- 510
Navigation equipment	- Automatic pilot, Decca
Navigator	- Decca 21
Plotter	- Decca 350
Crew	- 18, including masterfisherman and chief engineer

Acoustic equipment

EQ Simrad fishing sounder

SK 3 Simrad Sonar

38 kHz EK - S, Simrad Scientific Sounder (dry paper), with magnetic transducer type 68 BA mounted in separated block in the vessel's hull

QM - MK II Simrad Echo Integrator, coupled with Hewlett Packard storage oscilloscope

Acoustic calibration system consisting of a 204 C Hewlett Packard signal generator, Hewlett Packard 5381 A frequency counter, Hewlett Packard amplifier, voltmeter and LC 32 calibrated hydrophone

Krupp net sounder

The recorders of all instruments were mounted in panels in LEMURU's bridge

Fishing gear

For identification of echo traces and sampling to determine the species composition and the average length of the fish, LEMURU was equipped with two purse seines and a midwater trawl.

Normal size purse seine of length of corkline 450 m, depth 106 m, bunt mesh size 25 mm stretched. The dimensions were reduced to length 388 m and depth 56 m in September 1977.

Small size purse seine designed to catch fish for the calibration after attracting and concentrating them with both an underwater and a surface light. Length 60 m, depth 16 m, mesh size 20 mm stretched. The midwater trawl had a circumference of 308 meshes of 800 mm mesh size with 20 mm meshes in the codend. Further details on these gears are given in the report by Bjarnason (1979).

Oceanographic equipment

For collection of water samples Nansen's reversing bottles and, for vertical temperature structure, bathythermographs (0-60 and 0-140 m), were used. The determination of salinity was made with a Beckman conductivity bridge model RC 19 at the Fisheries Resources Bureau of Bahrain by Miss S. Al Alawi and Mr H. Sayed.

1.3.2 R/V MAJID

Characteristics of the vessel are as follows:

Country:	UAE
Material:	Steel
Type:	Stern trawler (shrimper) Purse seiner
Engine:	Caterpillar, 365 horsepower
Built:	1969
LOA:	22 m
GRT	100
Top speed:	8 kn
Sounders:	Simrad EQ, Simrad EY
Sonar:	Simrad SK
Radios:	Sailor SSB, Ensign VHF
Radar:	K. Hughes 48
Navigator:	Decca 21
Plotter:	Decca 350

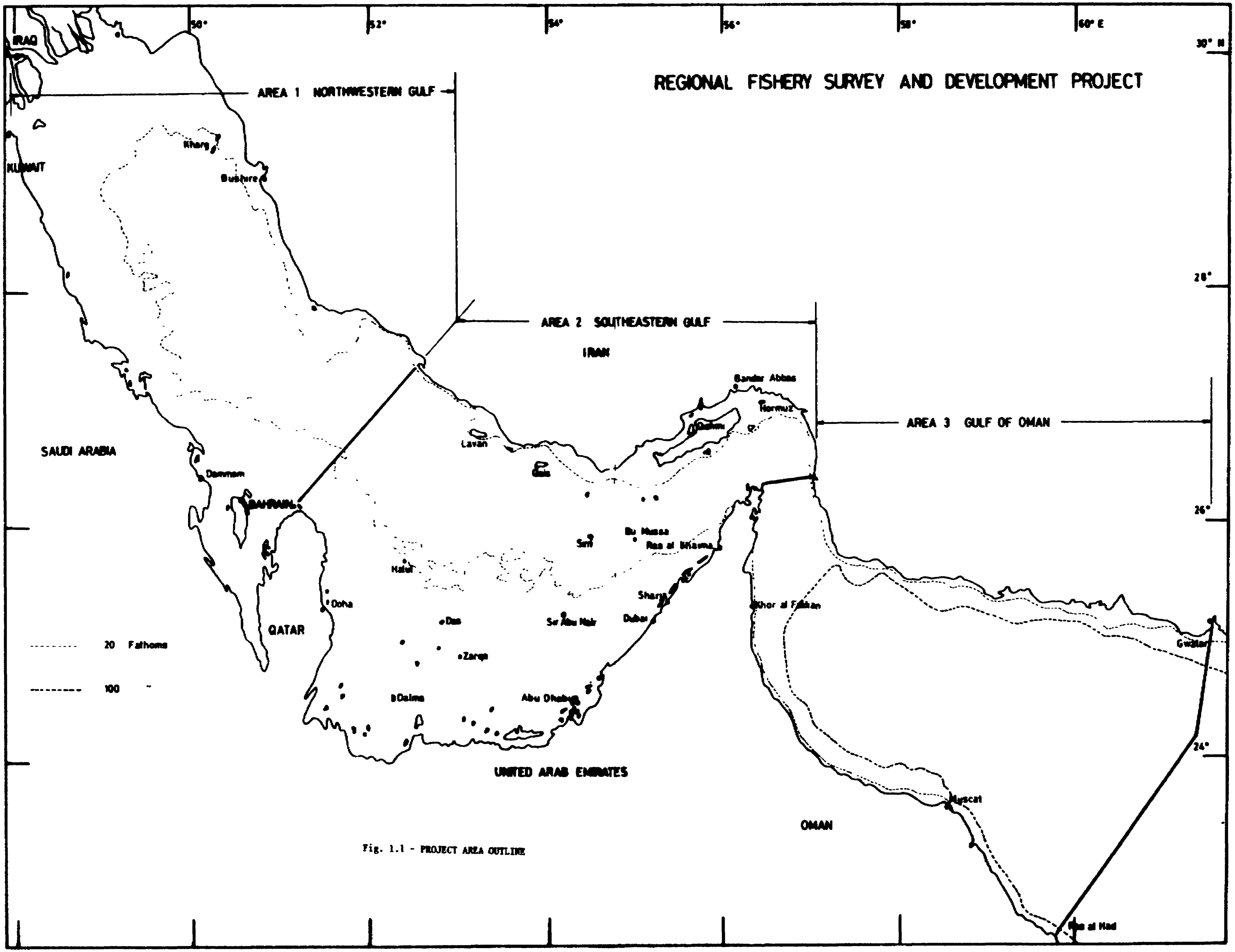


Fig. 1.1 - PROJECT AREA OUTLINE

2. REPORT ON THE PRELIMINARY PHASE OF THE ACOUSTIC SURVEY FOR SMALL PELAGIC STOCKS IN THE SOUTHEASTERN GULF (MARCH-AUGUST 1977)

by

Julio Vidal-Jünemann

2.1 INTRODUCTION

Prior to the main acoustic survey with the R/V LEMURU, it was decided that preliminary work should be undertaken to study aspects of the biology, distribution and behaviour of the fish as well as the environmental conditions in the area, as a basis for the design of a survey plan for the main survey.

The area selected for these preliminary experiments was the southeastern Gulf between Bahrain and the United Arab Emirates (see Fig. 1.1), in view of the fact that this area was known to contain significant pelagic resources, particularly sardine. A fishmeal plant exploiting the nearby sardine concentrations was already in operation in the UAE and another was under construction; therefore information on the available resources was urgently required.

2.2 METHODS AND EQUIPMENT

2.2.1 Survey Method

The main objectives of the preliminary phase were to obtain information on the size and distribution of the sardine schools, and to make a comparison of the number and sizes of fish schools per unit area of the sea surface observed with a vertical echosounder and echo-integrator system, and those obtained with a nearly horizontally transmitting sonar.

A list of cruises with their objectives is given in Table 2.1. During most cruises in the Gulf a track consisting of parallel lines 20 mi apart was followed and in the Gulf of Oman a sawtooth track (Figs. 2.1 and 2.2). Along these tracks continuous recordings were made with the echo integrator and with the sonar. Fishing was carried out in schools when required for sampling purposes.

Table 2.1

R/V LEMURU CRUISES DURING THE PRELIMINARY PHASE

(MARCH-AUGUST 1977)

Cruise	Dates	Area Surveyed	Objectives, Activities
7701	10-17 March	Southeastern Gulf	Exploratory fishing Equipment testing
7702	26-28 March	Off Bahrain	Equipment testing
7703	9-21 April	South of Gulf of Oman	Acoustic survey
7704	8-19 May	Southeastern Gulf	Acoustic survey
7705	14-17 June	Off Bahrain	Fishing gear testing
7706	25 June - 9 July	South of Gulf of Oman	Acoustic survey Fishing Oceanography
7707	24-30 July	Eastern Gulf	Acoustic survey; Fishing; Oceanography
7708	9-18 August	Northern Gulf	Acoustic survey; Oceanography; Acoustic performance check

Throughout the survey, the surface water temperature was recorded every 30 min by means of an electric thermometer, and temperature and salinity observations at different depths were made with bathythermograph and Nansen water bottles, at selected stations of the cruise transects from May 1977 onwards. The position of the fishing and the oceanographic stations are indicated in Figs. 2.1 and 2.2. The water samples were analysed for salinity by means of a conductivity bridge salinometer at the Bahrain Fisheries Resources Bureau. The results of the oceanographic observations are presented in a separate report on environmental conditions (FAO, in preparation).

After several trials to obtain the best performance of the equipment in the environmental conditions prevailing at the time of the observations, the following control settings were adopted for the scientific sounder, the echo integrator and the sonar:

Echo sounder EK-S 38 kHz

Recorder range	-	A 0 - 50 m or B 0 - 100 m
Paper speed	-	A 25.2 or B 12.6 mm/min
Line density	-	100 lines/cm
TVG and gain	-	0 dB, 20 log R
Discriminator	-	4, variable
Mode	-	White line (WL)
Band width	-	Narrow, width 3 kHz
Pulse length	-	0.6 msec
Output power	-	1/1
Recorder gain	-	4
Scale and bottom switch	-	on

Echo integrator QM-MK II channels A and B

Gain	-	20 dB
Threshold	-	1, 2 variable
Interval	-	4 + 40 m (variable)
Scale expander	-	normal
Speed compensator	-	7, 8 knots (manual)
Operating mode	-	3 (n.mi) x 10
Reset	-	manually

Sonar-SK 3

Position of beam	-	fixed 90° to port side
Inclination of beam	-	2° down
Recorder range	-	1 - 1 500 m
Pulse length	-	20 msec
Gain	-	variable

The regular cruise speed of the vessel was 8 knots. The integrator and the scientific sounder were triggered and reset every 15 min, i.e., approximately every 2 n.mi. The information on the recorders at resetting time was entered in standard Cruise Log Forms for later analysis. The sonar was kept in a fixed position, 90° to port side, and the sonar echograms were read every hour and the number of contacts recorded for every mile steamed along the acoustic survey tracks. During fishing operation the sonar was operated manually.

2.2.2 Processing Methods

2.2.2.1 Sonar readings

With the sonar setting at the 0-1 500 m range, the number of schools (contacts) per units of distance from the transducer were recorded. On the basis of the number of schools in relation to distance, a range was selected between which the counts were believed representative for the average school density (150-1 000 m). Fig. 2.3 shows this range in relation to the sailing vessel.

This range-area factor was utilized to transform the number of schools detected into the number of schools per unit surface area. The density observed during each nautical mile sailed by the vessel was expressed as number of fish schools per square nautical mile.

The calculated densities were plotted along the survey track and contour lines were drawn according to the following scale:

Stratum	No. of schools/n.mi^2	Relative abundance rating
I	1 - 20	low
II	20 - 40	medium
III	> 40	high

The area encompassed by each contour line was determined by planimeter and the total number of schools per stratum was calculated. This number was later transformed into fish biomass using information on school size in terms of weight. The estimated total biomass was calculated according to the following computations:

$$\hat{W} = \sum_{i}^{n} A_i \, \hat{\bar{\rho}}_i \qquad (1)$$

where,

A_i = surveyed area in Stratum i

$\hat{\bar{\rho}}_i$ = estimated average fish school density per n.mi^2 in Stratum i

further,

$$\hat{\bar{\rho}}_i = \bar{n}_{si} \; \bar{w}_{si} \qquad (2)$$

where,

$\bar{n}_{si}$ = estimated average number of fish school contacts per square nautical mile

$\bar{w}_{si}$ = estimated mean fish school size in tons

2.2.2.2 Echo integrator readings

A study of individual sardine schools provided useful information on parameters of the school such as depth, height and diameter, as estimated from the echo traces on the scientific sounder following Smith (1971), Johannesson and Losse (1973), and Vidal and Johannesson (1976).

For the estimation of the school diameter it was assumed that the schools had a cylindrical shape, with a height (h) and diameter (d_c). The apparent diameter (d), as measured from the trace on the paper needs to be corrected for beam width, and depth, and also by a statistical factor based on the fact that a school will only rarely be transversed exactly through its centre. The mean diameter estimated for a number of schools of the same size is given by $\bar{d} = \frac{\pi}{4}d$. Thus the volumes estimated from echo records of these schools are on average underestimated by a factor of $(\frac{\pi}{4}^{-2})$, i.e., by nearly 40% (Olsen, 1969).

For the computation of school volumes, fully corrected diameters were used in the formula: $V = \frac{1}{4}\pi d_c^2 h$.

The echo integrator readings per elementary sampling distance unit (1 n.mi) provided an index of the fish abundance in the path of the vertical echosounder beam. These indices were plotted on a map, and contour lines along points of equal value drawn. This provided a picture of the fish distribution, which can be compared with the map of the distribution obtained from the sonar observations.

During the main phase of the survey, live-fish calibrations were carried out to convert the integrator readings into estimates of absolute fish abundance (see Lamboeuf and Simmonds, part 3 of this report). However, different instrument settings were used during the two phases. In order to obtain an estimate from this preliminary survey for comparison with the results from the main phase, Simmonds provided a conversion factor based on theoretical considerations of the integrator performance under the different conditions, which is reflected in the calibration constant C given below.

As most of the small pelagic fish schools encountered in the southeastern Gulf area were formed by the sind sardinella (Sardinella sindensis), the following constant values were introduced to transform the integrator readings into absolute biomass:

day readings $C = 9.54$ t/mm/n.mi^2 ref. to 1 n.mi
night readings $C = 5.30$ t/mm/n.mi^2 ref. to 1 n.mi

It was considered to be night from 19.00 to 05.00 h (cruise 7704, May 1977).

The calculated biomass was then plotted along the track and the following scale was adopted in order to contour the biomass stratified by density interval:

Stratum	Density t/n.mi^2	Relative abundance rating
I	1 - 50	low
II	50 - 100	medium
III	100 - 200	high
IV	> 200	very high

A chart of abundance and distribution was then produced. Individual biomass estimates were obtained for every stratum and the biomass for the total survey area was obtained by summation of the estimates for each stratum. The following computational steps were followed:

$$\hat{W}_i = \sum_i^n A_i \hat{\bar{\rho}}_i \qquad (3)$$

where,

W_i = estimated total biomass in weight in Stratum i

A_i = area surveyed in Stratum i

$\hat{\bar{\rho}}_i$ = estimated average fish density, in t/n.mi^2 in Stratum i

further,

$$\hat{\bar{\rho}}_i = m_i C \qquad (4)$$

where,

m_i = estimated average integrator reading per unit sampling distance of 1 n.mi, in Stratum i

C = calibration constant on the basis of which the integrator readings were converted into t of fish/n.mi^2

The total estimated biomass for the whole area surveyed in the southeastern Gulf was then obtained by:

$$\hat{W} = \sum_i^n \hat{W}_i \qquad (5)$$

2.3 RESULTS

2.3.1 Summary of Cruises 7701-7708

The preliminary phase of the acoustic survey, from March to August 1977, consisted of 8 cruises of different duration (Table 2.1., Figs. 2.1 and 2.2):

Cruise 7701. A cruise for familiarization with the southeastern Gulf area combined with exploratory fishing and a courtesy visit to Dubai. Schools of sind sardinella were detected in shallow waters. Midwater trawl samples indicated sind sardine as the predominant small pelagic species followed by small carangids and anchovies. This cruise provided surface temperature recordings and school size estimates from sonar recordings.

Cruise 7702. A short cruise to test fishing gear and acoustic equipment off Bahrain.

Cruise 7703. A cruise for familiarization with the Gulf of Oman combined with a courtesy visit to Muscat. The presence of small pelagic schools in coastal waters and myctophid concentrations in deeper waters was recorded.

Cruise 7704. An acoustic survey cruise combined with fishing for species identification. This cruise provided the best coverage of the southeastern Gulf during the preliminary phase. Therefore, the data collected with sonar and echo-integrator have been utilized to estimate the biomass of small pelagic species and to compare both approaches. The results of this cruise will be discussed in detail.

Cruise 7705. Fishing gear testing off Bahrain/Qatar, to improve the fishing performance of the purse seine in preparation for the cruise in the Gulf of Oman.

Cruise 7706. An acoustic survey in the Gulf of Oman area up to Ras Al Hadd, combined with hydrography and fishing for species identification. Some small pelagic schools of sind sardinella, Indian oil sardine (*Sardinella longiceps*) and small carangids were found in the coastal waters. Huge concentrations of myctophids were detected in deep waters. The survey could not be extended to the Iranian coast as planned because Iranian Government clearance was not obtained in time.

Cruise 7707. An acoustic survey combined with oceanographic stations and some fishing in order to complete the southeastern Gulf hydrographic coverage initiated during the previous cruise.

Cruise 7708. Familiarization with small pelagic resources distribution on the Iranian side of the northern part of the Gulf, combined with a courtesy visit to Bushehr. A performance check of the acoustic equipment was also carried out.

2.3.2 Biological Sampling

The samples of small pelagic species taken in the southeastern Gulf from March to August 1977 indicated that the predominant species was the sind sardinella (90% of the total catch) and scads (Carangidae) and anchovies (*Stolephorus* sp.) (together 9%).

Regular sampling for sardine size composition was conducted. Fig. 2.4 illustrates the size composition of sind sardinella from March through August 1977, and the length/weight relationship for the samples taken in June and July 1977.

Fig. 2.5 gives the size frequency distribution for some specimens of the rainbow sardine (*Dussumieria acuta*) fished in May and June 1977. The length/weight relationship for this species is also included, based only on one sample taken in June 1977.

2.3.3 Results from the Sonar Recordings

2.3.3.1 Hydrographic conditions in the southeastern Gulf relating to sonar performance

The hydrographical observations collected during the whole survey are dealt with in detail in the report on environmental conditions (FAO, in preparation).

The results of the hydrographic conditions in relation to the use of the sonar can be summarized as follows. The southeastern Gulf between Qatar and the Strait of Hormuz is a relatively shallow area mainly within the 50 m isobath (Fig. 1.1). In this area the wind is an important agent responsible for accelerating the circulation pattern of the water masses. As observed during these cruises, the eastflowing waters from the upper Gulf come over the tip of the Qatar Peninsula, turning south/southeast, over the whole shelf towards the Strait of Hormuz. The current is accelerated by the west/northwest wind called "shamal", which homogenizes the waters down to a depth of approximately 30 m.

The relatively cold months, from about October to April/May, are windy months with surface temperatures of 22°-24°C. Only during periods of calm weather can some brief vertical stratification be observed with a difference in temperature of 3°C between surface and bottom water. Therefore, the vertical temperature structure is almost homogeneous and appropriate for the performance of a sonar.

The reverse situation occurs during the summer. Due to intensive solar radiation, the surface temperature increases monthly up to a maximum of 30°-40°C (July through September). The existence of a thermal stability with the formation of a thermocline around 25-30 m is a common situation only broken temporarily by short periods of strong westerly/northwesterly winds. This strong thermal stratification precluded the use of the sonar for pelagic school mapping (FAO, in preparation).

2.3.3.2 Effective sonar beam range

In order to study the effective sonar beam range, the schools were grouped according to distance from the sonar transducer. Table 2.2 summarizes the information on the number of schools per unit distance from the sonar transducer. The frequency of schools per 250 m and 400 m distance interval is given in Figures 2.6 A and B respectively.

Table 2.2

FREQUENCY OF SCHOOL CONTACTS BY DISTANCE
FROM THE SONAR TRANSDUCER. LEMURU CRUISE 7704, MAY 1977

Distance interval (m)	Frequencies	
	No. of Schools	%
0- 250	720	9.6
250- 500	2 436	32.5
500- 750	2 454	32.8
750-1 000	1 250	16.7
1 000-1 250	4	0.1
1 250-1 500	622	8.3
Total	7 486	100.0

A small number of schools was detected within the first 100 m from the vessel, possibly resulting from two factors: (i) a number of schools were avoiding the vessel; (ii) a number of schools were not detected due to the beam and receiver characteristics. The decrease in contacts beyond the 750-1 000 m interval was considered to be attributable to range dependent loss (FAO, in preparation).

Therefore, an interval from 150 to 1 000 m was selected for sampling the fish school recordings. This interval gave a 850 m path of insonification equivalent to an effective insonified area of 0.459 n.mi^2/nautical mile sailed (Fig. 2.3).

Table 2.3

FREQUENCY OF SCHOOL CONTACTS BY TIME OF DAY.
LEMURU CRUISE 7704, MAY 1977

Time of day (h)	Distance range in metres from sonar transducer					
	0-1 000		1 000-1 500		0-1 500	
	No.	%	No.	%	No.	%
00.00-03.00	506	7.2	12	1.7	518	6.6
03.00-06.00	521	7.4	6	0.8	527	6.8
06.00-09.00	1 143	16.2	126	17.5	1 269	16.3
09.00-12.00	1 201	17.0	193	26.8	1 394	17.9
12.00-15.00	1 643	23.2	256	35.5	1 899	24.4
15.00-18.00	669	9.5	46	6.4	715	9.2
18.00-21.00	839	11.9	63	8.7	902	11.6
21.00-24.00	539	7.6	19	2.6	558	7.2
Total	7 061	100.0	721	100.0	7 782	100.0

2.3.3.3 Frequency of school contacts per time of day

The total number of school contacts detected during the whole 7704 cruise are summarized in Table 2.3 and Fig. 2.7 per 3-h interval for 0-1 000 m, 1 000-1 500 m and 0-1 500 m.

The number of contacts increased the ranges from 06.00 h to a maximum around mid-day and then decreased until 21.00 h. It was observed that the schools started to disperse around 19.00 h, well after sunset, and regrouped at dawn, around 05.00-06.00 h.

2.3.3.4 Estimates of weight of school

The school size of weight estimate was obtained by LEMURU's skippers' judging of sonar contacts based on their fishing experience with sonar. The skippers recorded the estimated weight of fish school contacts along the vessel's track and in particular when it was planned to set the net. Fig. 2.8 shows the frequency distribution for these school size estimates based on cruises 7701, 7703 and 7704. These sardine schools were very small, with 89 percent of the school contacts studied under 4 t estimated weight. The mean weight of the school thus estimated was 2.58 t. This figure was used in biomass computations.

The information on school size thus collected and the information gained on fish schooling behaviour were confirmed during a visit to the Ras Al Khaimah Fishing Company in November 1977. The skippers of this company corroborated that the sardine schools were fast-moving small schools, generally under 10 t, with the majority below 4 t. Only a few sardine schools of over 10 t were fished within the operational range of the Ras Al Khaimah fishing fleet (see part 4).

The estimated mean weight of 2.58 t was compared with the catch per set observed in the Ras Al Khaimah fishery. The value of 5.77 t/set given by Scheffers (see part 4) represented the highest catch rate of the fishing year. This figure may be a considerable overestimate of the average school size, because the skippers would tend to set on the bigger schools. Also fish behaviour and biological factors could have produced large schools in early spring in this area, not observed in the rest of the southeastern Gulf. The value for mean annual catch per set of 2.96 t in 1977 would be biased because of the selection of the bigger schools by the skippers; however, this value is very similar to the estimated mean school size based on LEMURU's observations.

2.3.3.5 Abundance and distribution from sonar recordings

Fig. 2.9 A gives the frequency of density readings observed during cruise 7704, May 1977, in the southeastern Gulf, while Fig. 2.10 gives the relative abundance and distribution of small pelagic schools at that time.

Considering the area occupied by the different strata, it appeared that 91.6% of the total area surveyed corresponded to Stratum I with a mean density of 8.72 schools/n.mi^2; 7.6% corresponded to Stratum II with a mean of 24.53 schools/n.mi^2, and finally only 0.8% of the total area was occupied by Stratum III with a mean of 51.12 schools/n.mi^2.

The total surface occupied by the combined Strata I and II (low and medium abundance) represented 99.2% of the area, which indicates the relative low density of sardine schools in the southeastern Gulf during May 1977. High fish school concentrations were detected only in certain areas north of the Qatar Peninsula, close to Halul Island, north of Abu Dhabi and in front of Ras Al Khaimah (Fig. 2.10).

From the density distribution chart (Fig. 2.10) the total number of schools per stratum was calculated and this figure combined with an average school size of 2.58 m produced the biomass estimates given in Table 2.4. The figure thus obtained of 613 023 t represented the total estimated biomass for the resources of small pelagics in the surveyed area of the southeastern Gulf. Given the total surveyed area of 23 195 n.mi^2, the overall density of small pelagic fish was 26.43 t/n.mi^2, varying from averages of respectively 22.5 and 63.3 t/n.mi^2 in the low and medium density areas to 131.9 t/n.mi^2 in the high density areas.

2.3.4 Results Obtained by Echo-Integrator and Echosounder

2.3.4.1 Estimation of school parameters

Data on school sizes of sardines collected by R/V LEMURU during cruises 7701, 7704, 7706 and 7707 in the southeastern Gulf were analysed. In Table 2.5 the values for mean school depth, height and estimated diameter are given for daylight hours (5-19 h) dark hours (19-5 h) and for the whole day.

School depth

The mean school depth1/ distribution has been plotted in Fig. 2.11. The mean depth of occurrence of sardine schools in the southeastern Gulf area fluctuated from 18.5 to 85 m with 78% of the measured schools being present at a depth of less than 30 m.

This indicates that the sardine schools in the southeastern Gulf area occur close to the surface. The schools registered during cruise 7706 at depths between 50 and 80 m might well consist of other species, e.g., carangids.

School height

Fig. 2.12 illustrates the school height observed during the mentioned cruises. The average school height values fluctuated from 3.9 to 5.4 m, with 67% of the individual fish schools under 6 m of total school height, which confirms the observation of the small dimensions of the schools in this area.

School diameter

The school diameters corrected for the acoustic fore-aft beam angle and the statistical correction for the probability of crossing the centre of the school, are given in Fig. 2.13. The mean school diameter observed during these cruises oscillated from 24.6 to 30.6 m, with 87 percent of the recorded schools being under 40 m in diameter (Table 2.5).

School volume

The mean school volumes calculated for the four cruises are given in Table 2.5.

In summary, the measurements on sardine schools indicate that the individual sardine schools in the southeastern Gulf were very small, with an average height around 4-5 m and an average diameter of less than 30 m and that they concentrated at depths usually not exceeding 30 m.

2.3.4.2 Abundance and distribution estimated by echo-integrator

The echo-integrator data collected during R/V LEMURU's cruise 7704 conducted in May 1977 was utilized to obtain another estimate of distribution and biomass of small pelagic species resources in the southeastern Gulf.

The calibration constants C, given in section 2.2.3.2 were used to convert the integrator readings in mm of fish into tons. The frequency distribution of the biomass estimation per mile sailed is given in Fig. 2.9 B. The stratification of fish densities in four stratawas based on this figure. The fish distribution based on this stratification is given in Fig. 2.14. The distribution is very similar to the chart based on the sonar recordings (Fig. 2.10). There are some minor differences in fish concentrations due to the finer stratification applied to the integrator's readings. The low density stratum occupied almost the whole surveyed area of distribution Medium and high densities are only present in patches northeast of the Qatar Peninsula, around Halul Island, northwest of Dubai and north of the Ras Al Khaimah area (Fig. 2.14). A few very high concentrations, over 200 t/n.mi^2, were detected northeast of the Qatar Peninsula. Most concentrations of small pelagic resources were distributed only a little beyond the 50 m (20 fathom) depth contour.

1/ It is assumed that this value indicates the depth of the centre of the school

Table 2.4

ABUNDANCE ESTIMATES OF SMALL PELAGIC SPECIES IN THE SOUTHEASTERN GULF, BASED ON SONAR RECORDINGS, MAY 1977

Locality	Area surveyed n.mi^2	No. of miles sampled	Average no. of schools/ n.mi^2	Total estimated no. of schools	Mean school weight (t)	Estimated abundance (t)	Mean density t/n.mi^2
Southeastern Gulf							
(North Qatar to Strait of Hormuz)							
Stratum I (1-20 schools/n.mi^2)	21 252	296	8.72	185 317	2.58	478 118	22.5 (low)
II (20-40 schools/n.mi^2)	1 769	43	24.53	43 394	2.58	111 956	63.3 (medium)
III (> 40 schools/n.mi^2)	174	8	51.12	8 895	2.58	22 949	131.9 (high)
Total	23 195	347	11.63	269 758	2.58	613 023	26.43

Table 2.5

MEAN SCHOOL DEPTH ($\overline{DM}$), MEAN SCHOOL HEIGHT ($\bar{h}$), MEAN SCHOOL DIAMETER ($\bar{d}_c$) AND VOLUME ($\bar{V}$) FOR THE SIND SARDINELLA (*SARDINELLA SINDENSIS*) SCHOOLS, AT DAY AND NIGHT SOUTHEASTERN GULF (MARCH-JULY 1977)

Cruise	Month	Hours	No. of schools measured	$\overline{DM}$ m	$\bar{h}$ m	$\bar{d}$ m	Volume ($\bar{V}$) m^3 1/
7701	March	05.00-19.00	40	18.8	4.1	26.7	2 294
		19.00-05.00	25	17.9	3.5	22.3	1 365
		Total/average	65	18.5	3.9	27.9	2 383
7704	May	05.00-19.00	143	23.9	4.9	22.5	1 947
		19.00-05.00	44	29.8	7.0	49.9	13 683
		Total/average	187	25.3	5.3	28.9	3 475
7706	June/ July	05.00-19.00	46	32.1	4.7	25.0	2 306
		19.00-05.00	19	26.7	5.7	23.9	2 556
		Total/average	65	31.3	5.0	24.6	2 572
7707	July	05.00-19.00	132	21.5	5.4	26.6	2 999
		19.00-05.00	50	18.2	5.5	41.4	7 400
		Total/average	182	19.5	5.4	30.6	3 969

1/ $\bar{V} = \frac{1}{4} \pi \bar{d}_c^2 \bar{h}$

$\bar{V} = \frac{\pi}{4} \bar{d}_c^2 \cdot \bar{H}$

Table 2.6

ABUNDANCE ESTIMATES FOR SMALL PELAGIC SPECIES RESOURCES IN THE SOUTHEASTERN GULF, BASED ON ECHO-INTEGRATION (MAY 1977)

Stratum	Fish density ($t/n.mi^2$)	Surveyed area ($n.mi^2$)	Number of miles sampled	Mean density ($t/n.mi^2$)	Standard deviation of mean density	Estimated fish biomass (t)	Average fish density ($t/n.mi^2$)
I	0- 50	18 284	220	18.68	11.94	341 545	18.63 (low)
II	50-100	1 825	41	67.66	13.38	123 479	67.66 (medium)
III	100-200	494	19	134.89	24.48	66 636	134.89 (high)
IV	> 200	157	5	336.20	90.04	52 783	336.20 (very high)
Total		20 760	285	40.63	61.05	584 443	28.15

Table 2.6 summarizes the biomass estimates per density stratum. The stratified estimates gave a total biomass of 584 400 t for small pelagic species in the southeastern Gulf, which is very similar to the biomass estimate obtained by the sonar method (613 023 t).

Stratum I, of low fish density, occupied 18 288 n.mi^2 or 88 percent of the total surveyed area, and contained 341 500 t or 58 percent of the total estimated biomass.

The overall mean fish density (total biomass/total area of fish distribution), gave a value of 28.15 t/n.mi^2 which is considered relatively low. This overall density figure is almost equivalent to the 26.43 t/n.mi^2 found by the sonar method for the same area of the Gulf and period of the year (Tables 2.4 and 2.6).

2.4 DISCUSSION

Though the sonar school frequency approach was utilized during May, in the early spring of 1977, the approach has its own limitations during the warmer months inside the Gulf area, thermal stratification and the formation of a strong thermocline being the major factors responsible for these limitations.

An advantage of sonar, as compared to an echosounder, is the greater water area covered, the effective insonified area being 0.459 n.mi^2 per every steamed nautical mile. On the other hand its range is often limited due to the modifications of the beam when encountering different density layers, e.g., strong thermal gradients (see report on environmental conditions FAO, in preparation). Furthermore, in shallow waters, where the sardines were distributed, problems were sometimes encountered in separating records of fish from those caused by bottom irregularities. Finally, the estimation of absolute abundance would require estimates of school size by weight, which are rather difficult to obtain. Also, the sonar only records the fish when in schools, in this case usually only during daytime.

The echo-integrator approach, not limited to the detection of fish in schools, but also recording dispersed fish and layers of fish, permits 24 h of continuous biomass recordings, thus providing a faster coverage. However, the fish in shallow waters often evades the ship's track on the approach of the vessel, and is therefore not recorded.

As has already been mentioned, the echo-integrator estimates of fish biomass had to be based on certain assumptions regarding the performance of the acoustic equipment, due to differences in the settings employed in the preliminary survey and in the main survey which included the live-fish calibration (see part 3). This does not affect the picture of fish distribution, however, which as mentioned in section 2.3.4.2 gave for both methods very similar results. Taking into account the limitations of both methods, the estimates of total biomass in the surveyed area, 613 000 t by sonar and 584 000 t by echo integrator, appeared to be similar (Table 2.7).

Table 2.7

ESTIMATES OF BIOMASS AS DETERMINED BY SONAR RECORDING AND ECHO-INTEGRATOR SYSTEMS

	Total area surveyed (n.mi^2)	Average fish density (t/n.mi^2)	Estimated biomass of small pelagic fish (t)
Sonar	23 195	26.43	613 000
Echo integrator	20 760	28.15	584 000
Average preliminary estimates			600 000

The observation that both methods give approximately the same answers indicates that the echo-integrator results were not seriously influenced by the avoidance of the ship by fish in shallow waters. The practical disadvantages of the sonar described above formed the reason to adopt the echo-integrator method as the main method during the main phase of the survey.

At the same time, the preliminary surveys provided a first estimate of the small pelagic fish biomass in the southern part of the Gulf, which, apart from being useful at the time of the survey, can be compared with the results of the main survey.

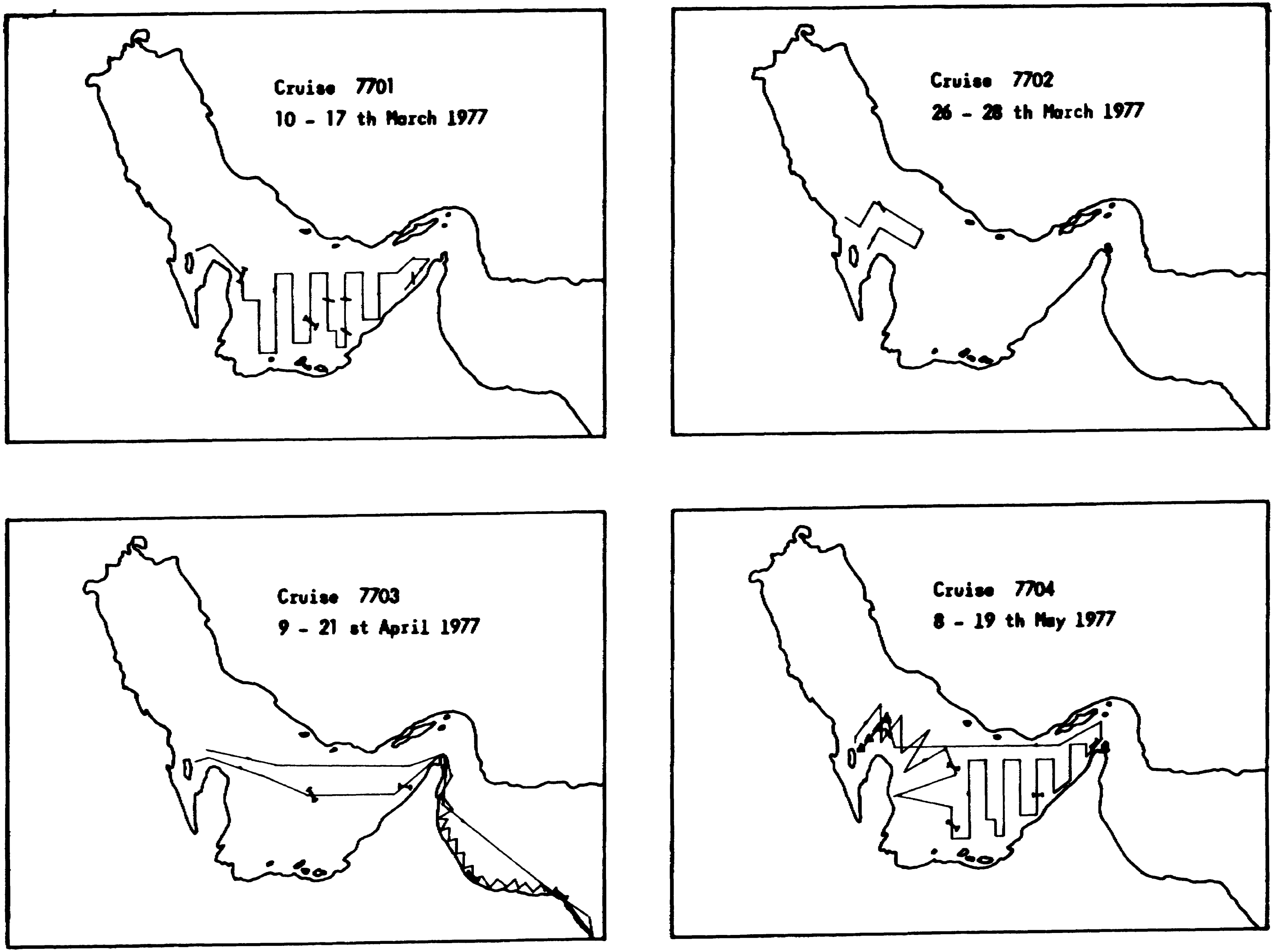


Fig. 2.1 R/V LEMURU cruises tracks and major sampling activities during the preparatory stage. March-May 1977.
Sampling stations = —— bottom trawl; ⟷ midwater trawl; ● purse seine, Δ hydrographic

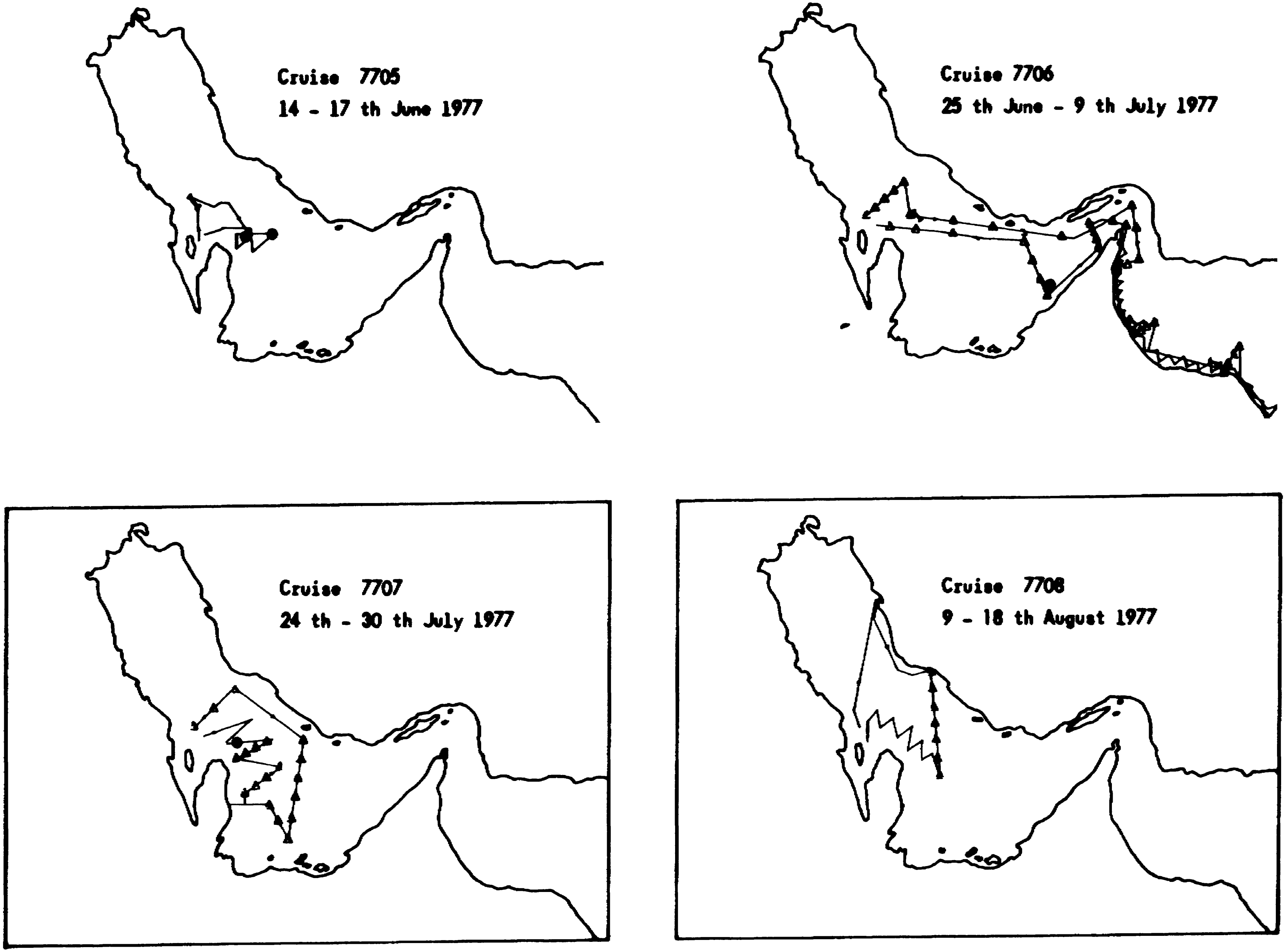


Fig. 2.2 R/V LEMURU cruises tracks and major sampling activities during the preparatory stage. June-August 1977.
Sampling stations = —— bottom trawl; ⟝⟞ midwater trawl; ● purse seine; Δ hydrographic

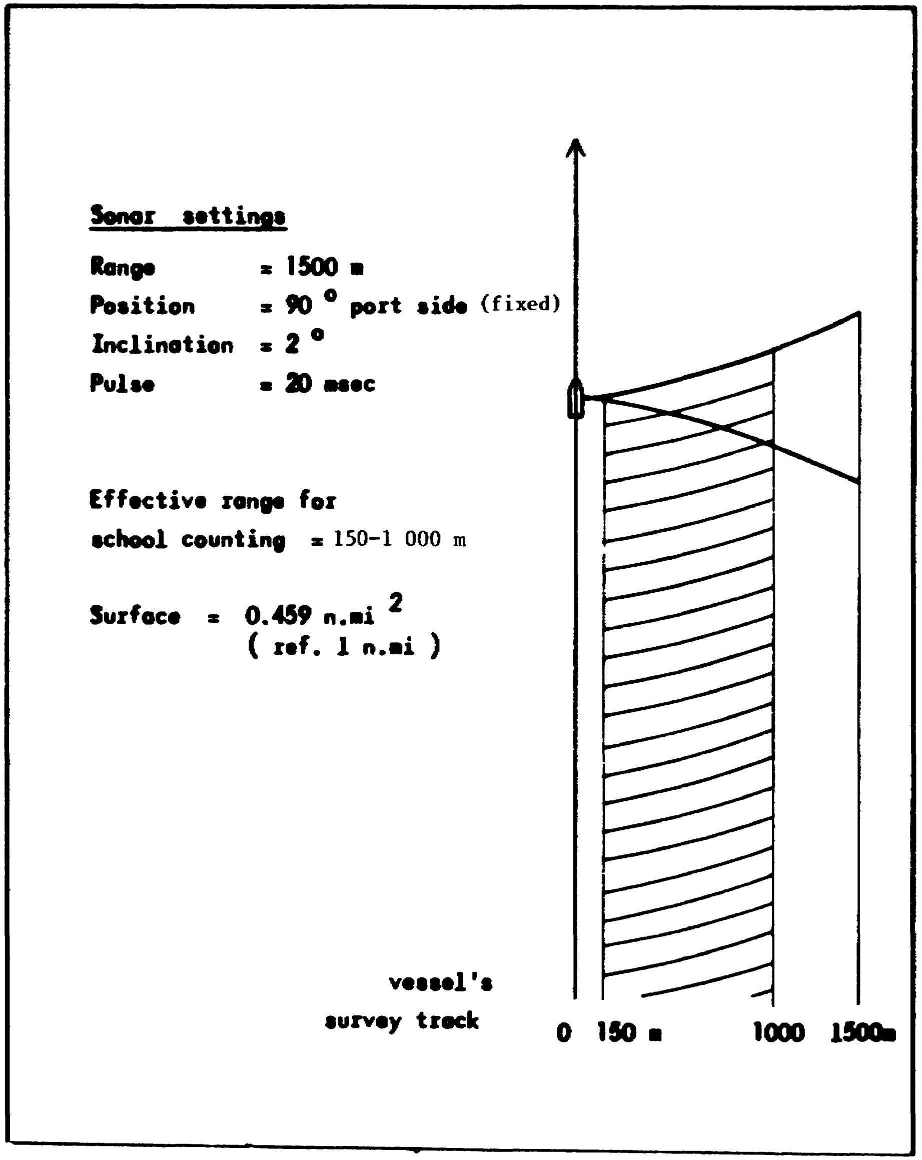


Fig. 2.3 Illustration of the effective sonar insonification area during survey track

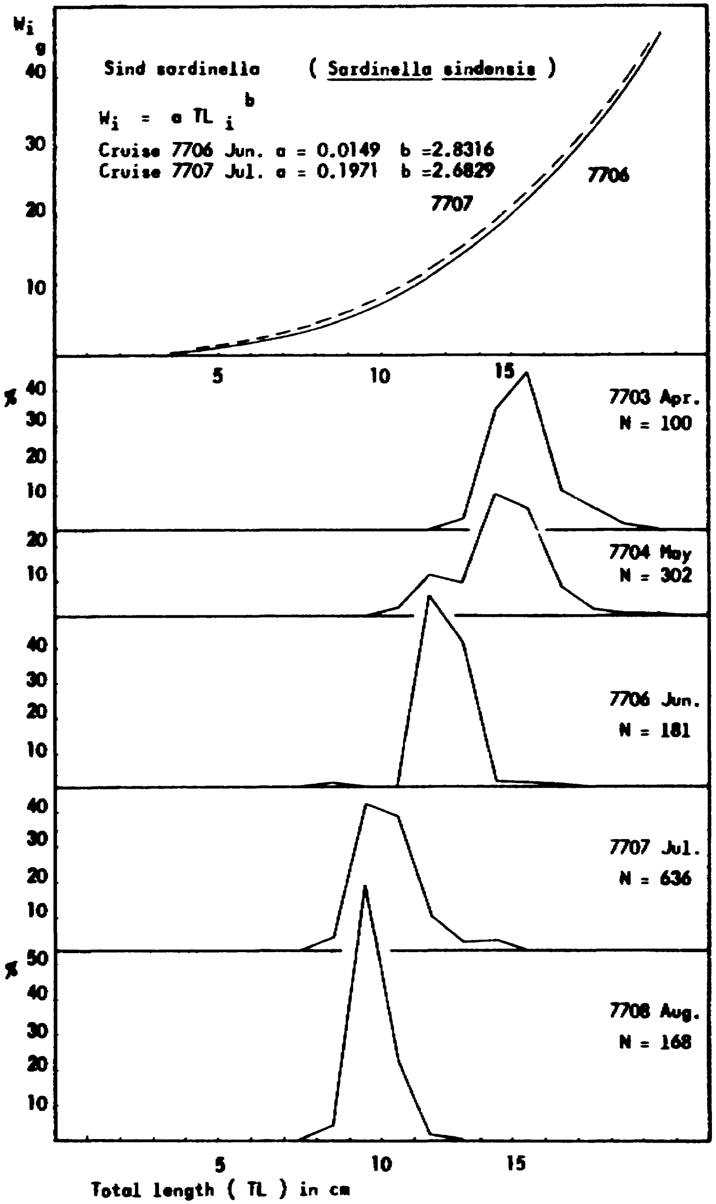


Fig. 2.4 Size distribution and length weight relationship for the sind sardinella (Sardinella sindensis)

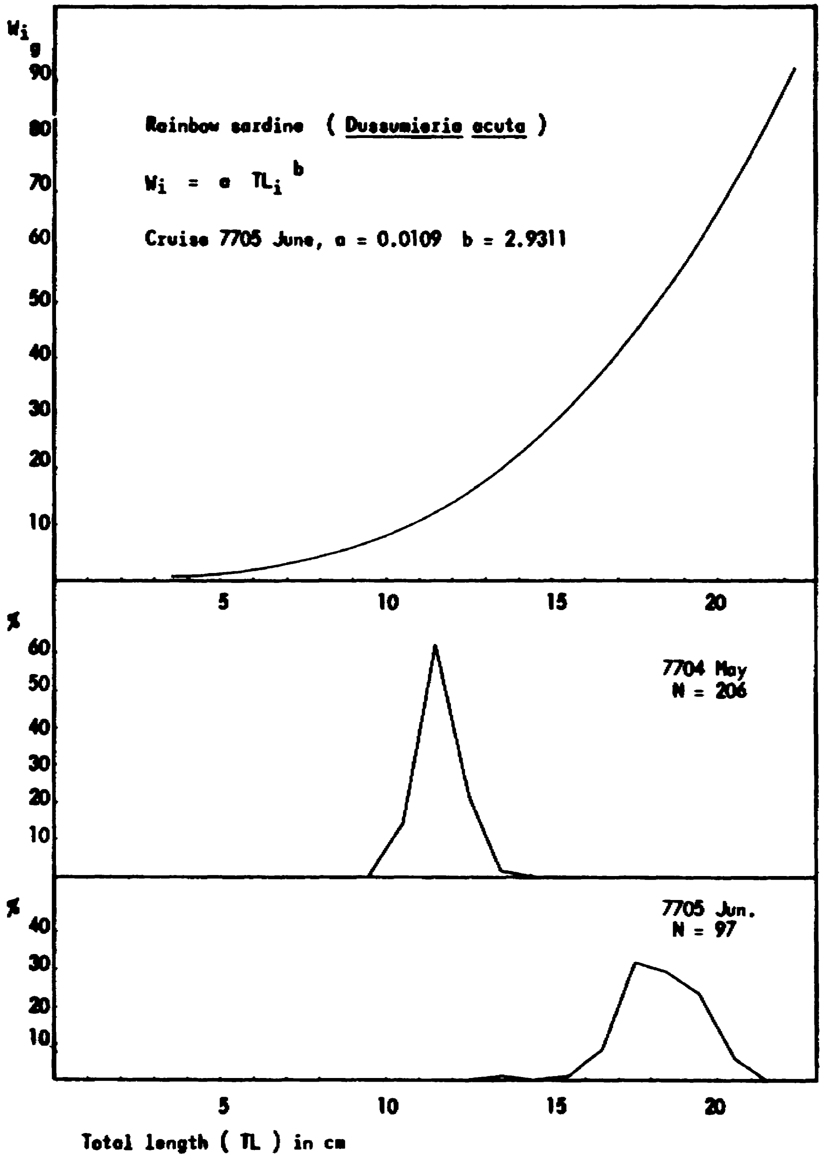


Fig. 2.5 Size distribution and length weight relationship for the rainbow sardine (Dussumieria acuta)

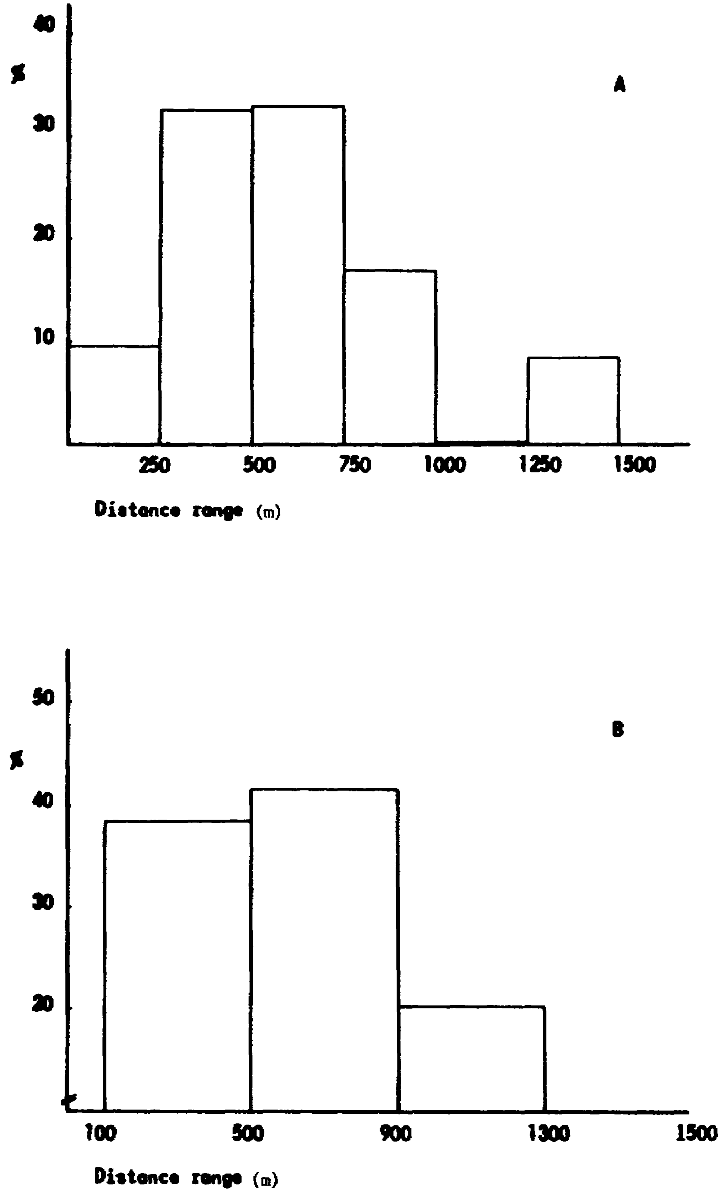


Fig. 2.6 Frequency distribution of schools contacts per distance from the sonar transducer: A at 250 m intervals, B at 400 m intervals

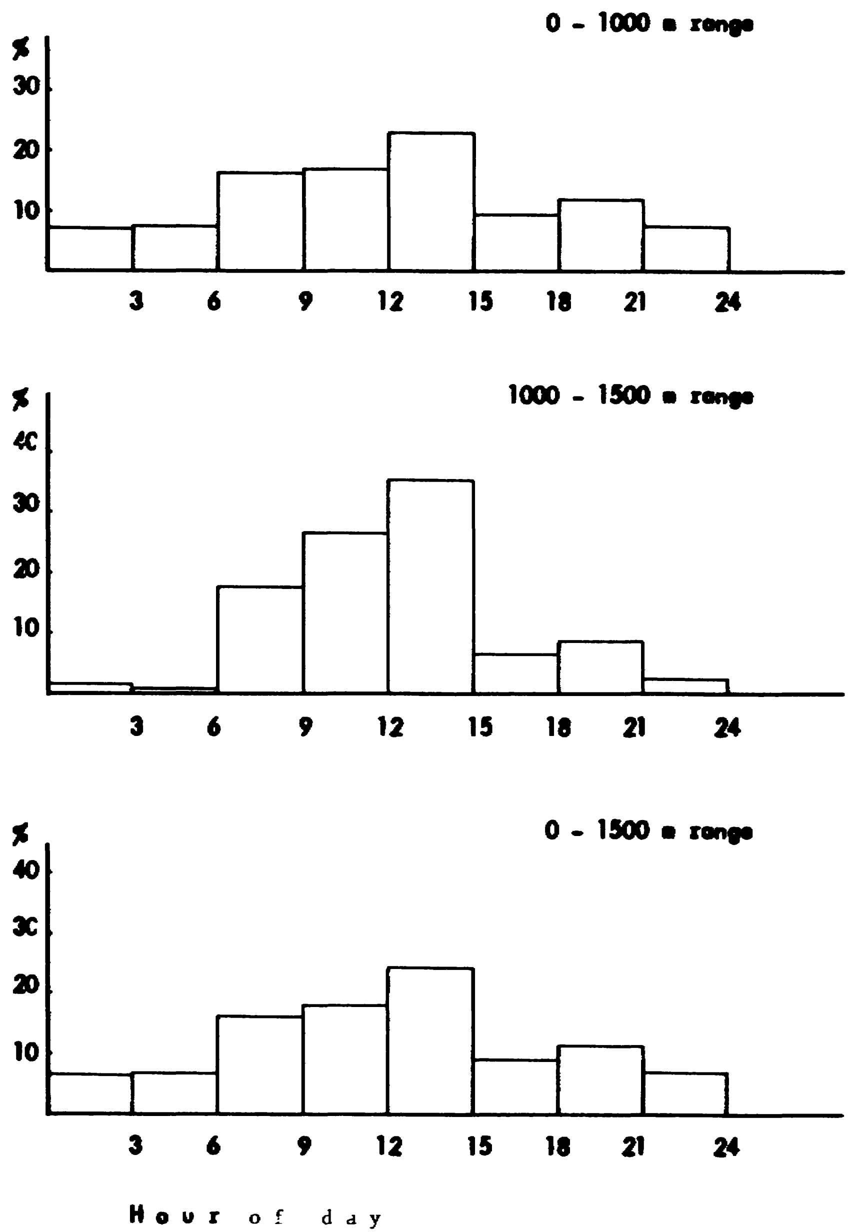


Fig. 2.7 Southeastern Gulf, May 1977. Frequency of sonar contacts by hour of day

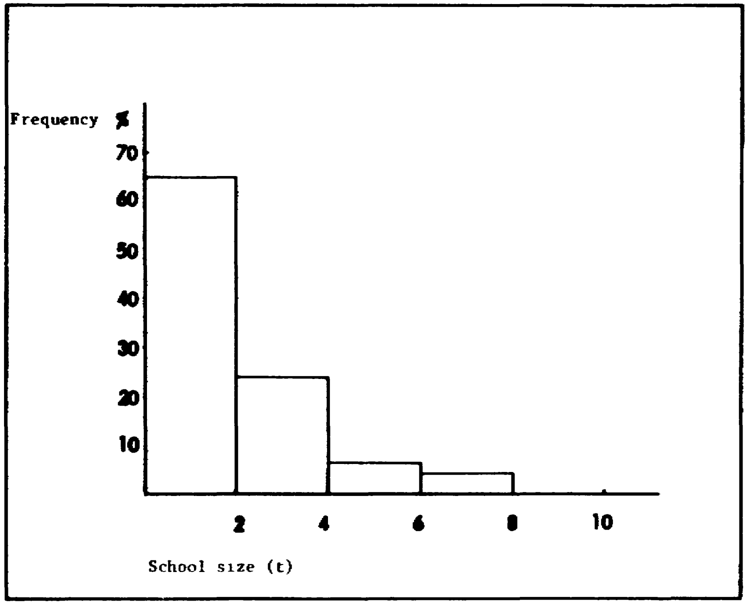


Fig. 2.8 LEMURU's sonar school size estimates for the southeastern Gulf, 1977

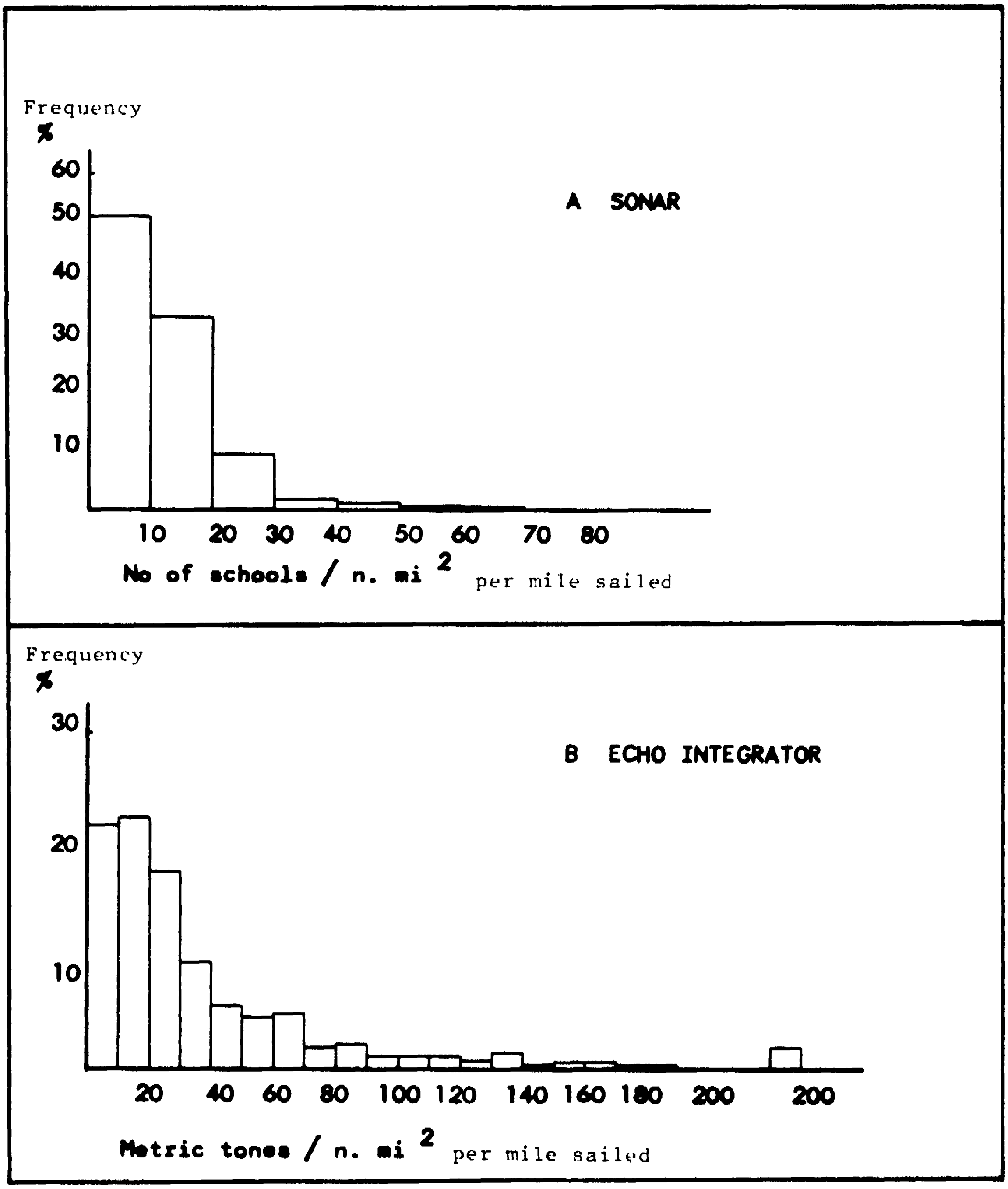


Fig. 2.9 Southeastern Gulf, May 1977. A, sonar, distribution of schools density readings, per nautical mile sailed. B, echo integrator, distribution of biomass readings per nautical mile sailed

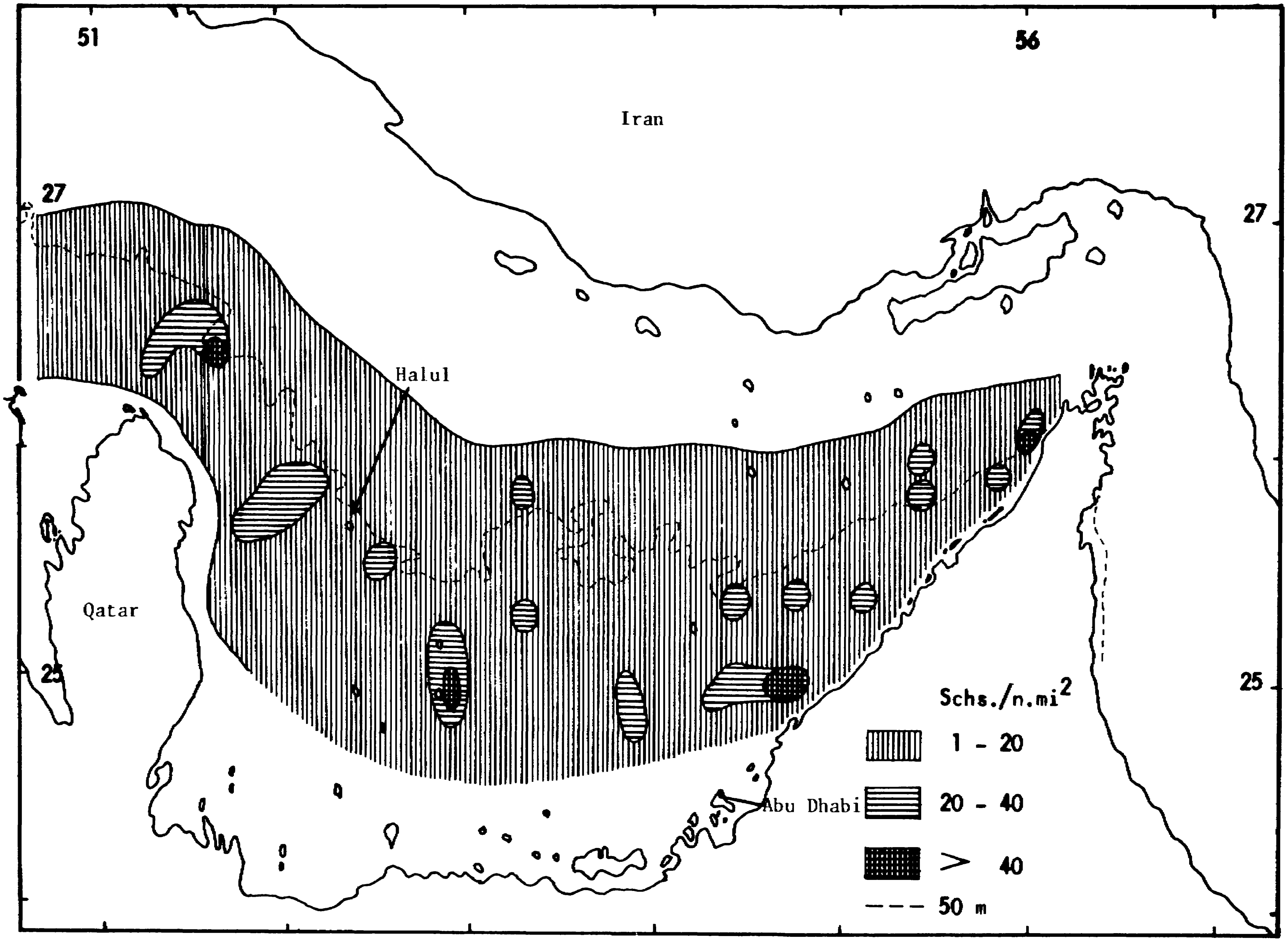


Fig. 2.10 Distribution of small pelagic resources in the southeastern Gulf, based on sonar readings during cruise 7704, May 1977

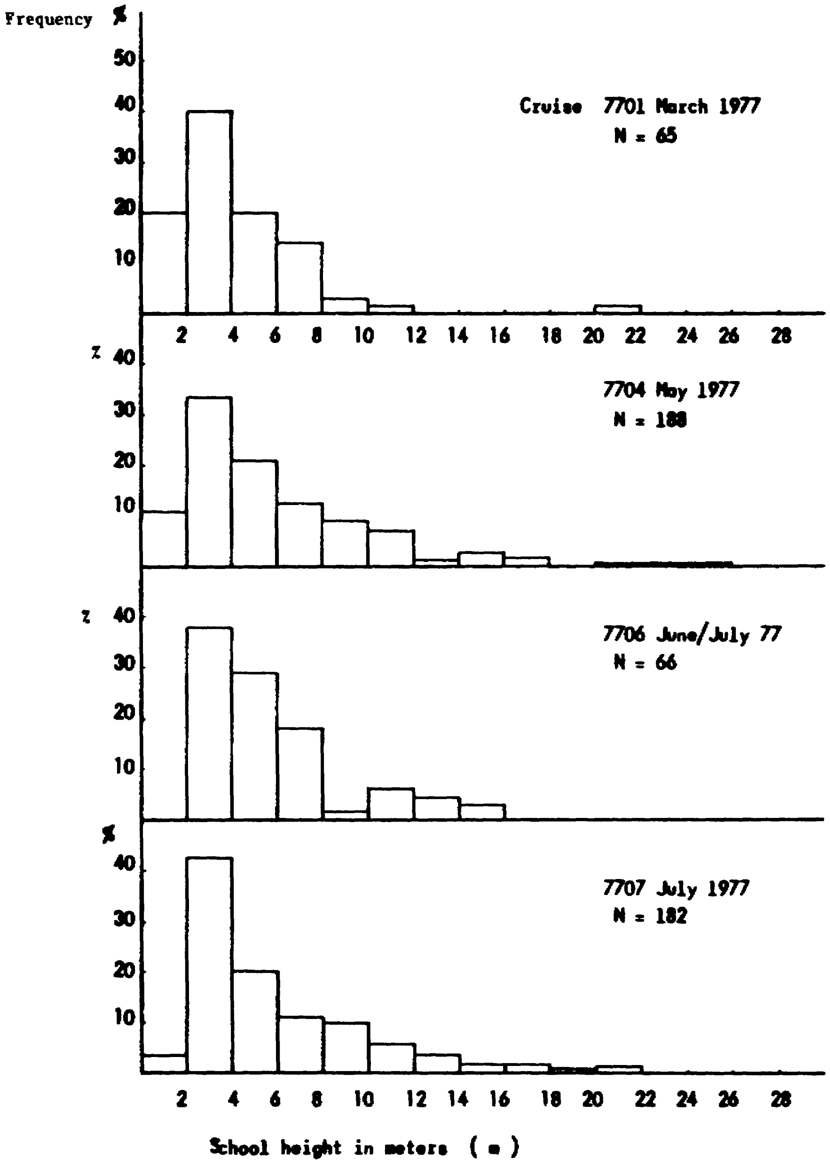


Fig. 2.12 School height for <u>Sardinella sindensis</u> in the southeastern Gulf area

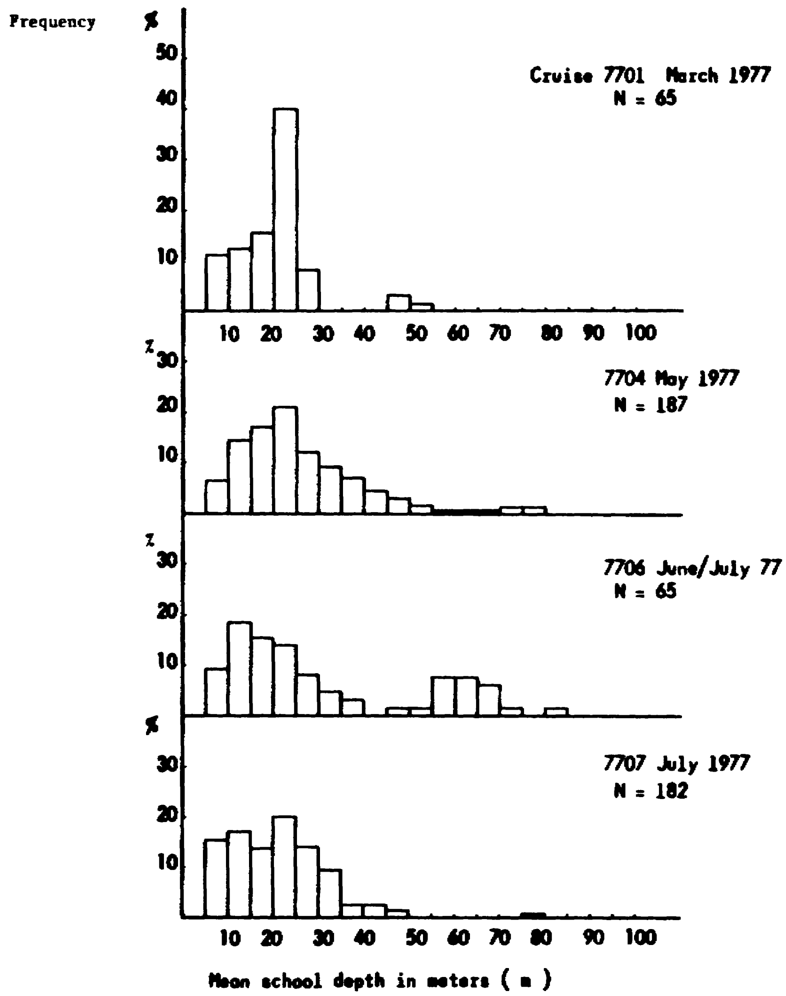


Fig. 2.11 Mean school depth distribution for <u>Sardinella sindensis</u> in the southeastern Gulf area

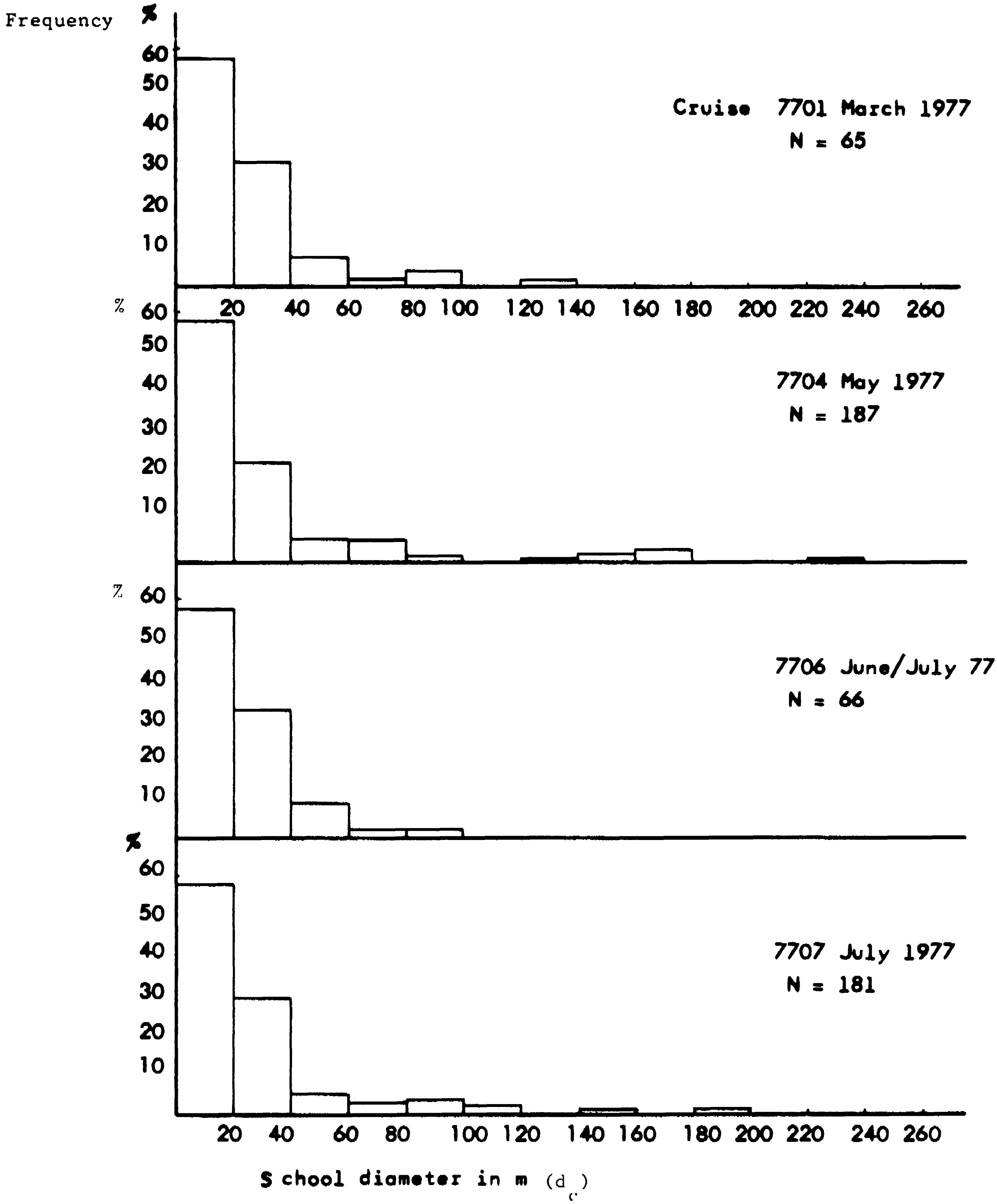


Fig. 2.13 School diameter for Sardinella sindensis in the southeastern Gulf area

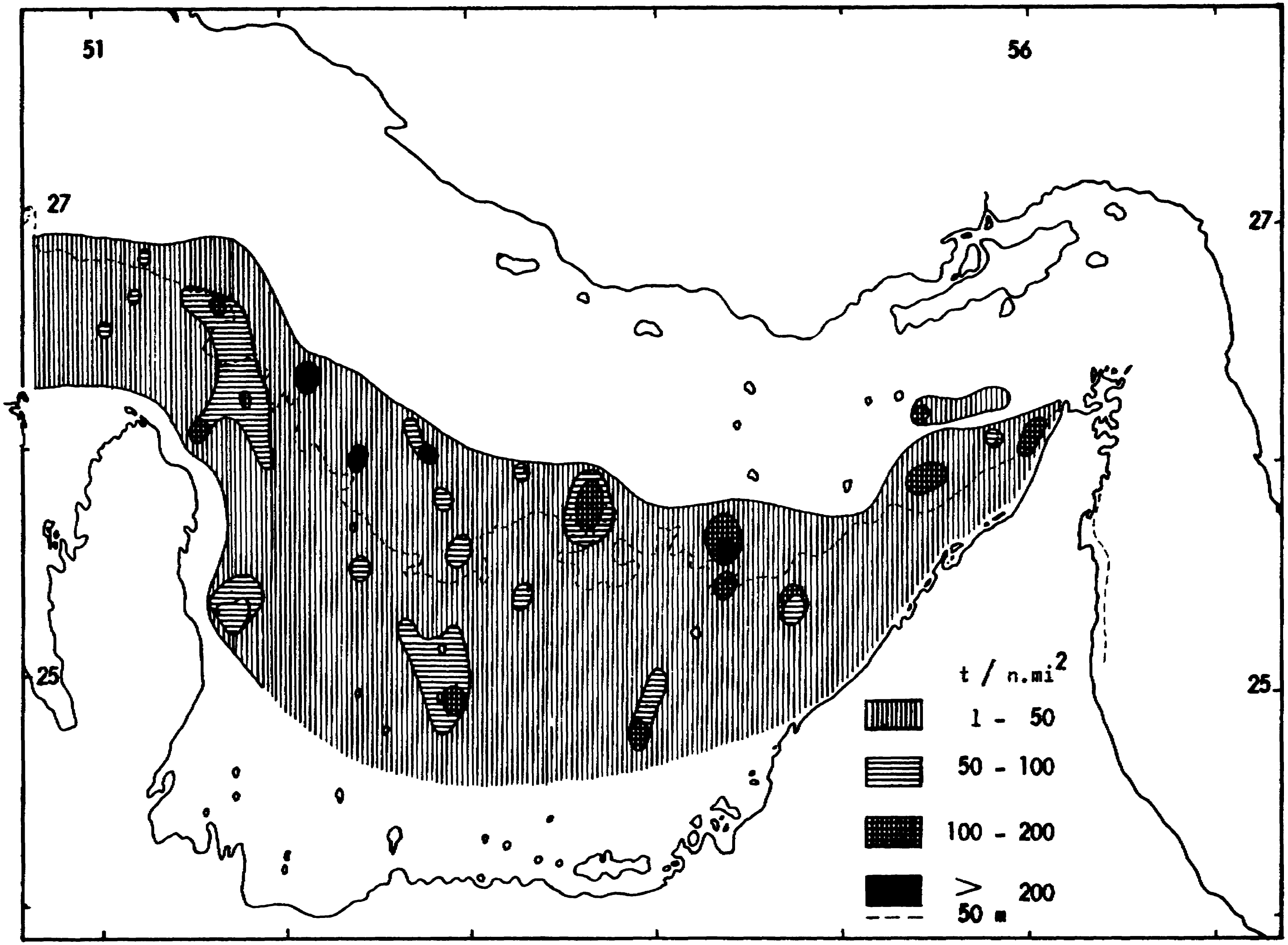


Fig. 2.14 Distribution of small pelagic resources in the southeastern Gulf, based on echo-integrator readings during cruise 7704, May 1977

3. ACOUSTIC ESTIMATION OF THE BIOMASS OF THE STOCKS OF SMALL PELAGIC SPECIES IN THE GULF AND THE GULF OF OMAN (SEPTEMBER 1977-OCTOBER 1978)

by

M. Lamboeuf and E.J. Simmonds

Acknowledgements

The assistance and contribution of all project staff, crew and counterparts, to this survey were invaluable and highly appreciated. The authors thank them all for their cooperation. Thanks are also extended to all member countries and government officials for their help and particularly for the facilities provided by the Fisheries Resources Bureau of Bahrain.

Special mention is made of Mr Darna and Mr Suanda, Indonesian crew members who greatly assisted in processing the data and drawings; and Prof. Gjøsaeter from the University of Bergen, Norway, for his analysis of the Myctophidae samples.

3.1 INTRODUCTION

One of the objectives of the Regional Fishery Survey and Development Project (RAB/71/278) was to estimate the size of the resources of the stocks of small pelagic species in the Gulf and Gulf of Oman. For this purpose, as recommended in the report of the first meeting of the *Ad hoc* Group on Survey Technique and Strategy it was decided to undertake an acoustic survey (FAO, 1976).

Taking into account the extent of the area, and the time factor, it was decided to cover the project area three times, in order to have an idea of the seasonal variations. The three coverages were preceded by a preparatory phase from March to August 1977 (see part 2).

From September 1977 to October 1978, the main acoustic survey was undertaken in the form of three seasonal coverages. The R/V LEMURU's activities and results during this period are described here. The R/V MAJID from UAE participated in the survey, working in cooperation with LEMURU and also alone, giving more emphasis to the southeastern Gulf. All the relevant results of the MAJID have been combined with those obtained from LEMURU and were incorporated in this part of the report.

3.2 ACOUSTIC EQUIPMENT AND INSTRUMENT SETTINGS

The acoustic equipment was classified as survey, test and calibration equipment:

(a) Survey equipment and settings

Sounder: Simrad EK-S38 and 38 kHz transducer 69M
(15 x 30/10 cm) used with following settings:

Output power	1/1
Receiver gain	OdB
TVG	20 log R/OdB
Pulse length	0.6 msec

Receiver bandwidth	3 kHz
Recorder gain	5
Mode	WL (white line)
Discriminator	6
Beam	narrow

Echo-integrator: Simrad QM MK II and Hewlett Packard recorder 7702B used with the following settings:

Gain	10 dB
Scale expander	X 10
Threshold	2
Speed Compensation	automatic
Bottom stop	ON

The sounder and integrator system has been modified to improve performance. A small circuit has been designed and included to improve the detection of the sea bed and to correct the evaluation of dense midwater schools. The precise action of this circuit, and a description is included as Appendix 1.

Sonar: Simrad SK 3 used with the following settings:

Range	0-750 m
Receiver gain	8
Bearing	90° (fixed)
Tilt	2° down (fixed)
Pulse length	long

(b) Test equipment

Oscilloscope	Hewlett Packard HP141B
Signal generator	Hewlett Packard HP204C
Frequency counter	Hewlett Packard HP5381A
Voltmeter	Hewlett Packard HP400FL 403
Attenuator Set	Hewlett Packard HP350D
Hydrophone	Brüel and Kjaer LC32 5739

(c) Calibration equipment

3 storage tanks for live fish (fibreglass coated with Jelcoat)

38 kHz Simrad Transducer. 69M (15 x 30/10 cm)

Calibration rig consisting of metal frame to support the transducer and a net cage, supported by two galvanized steel rings of 2.3 m diameter, with a height of 2.5 m

A more detailed description and a diagram of the rig are given in Section 3.4.

A series of performance measurements were carried out and the final results of these are shown below:

Table 3.1

PERFORMANCE MEASUREMENTS AUGUST 1977-OCTOBER 1978, REFERRING TO A SIMRAD EKS 38kHz SOUNDER WITH A 69 M (15 x 30/10 cm) TRANSDUCER

August 1977 to March 1978

Source level (SL) = +116.1 dB ref. 1μ bar
Voltage response (VR) = + 2.0 dB ref. $1V_{RMS}$/μ bar

April to June 1978

Source level (SL) = +115.5 dB ref. 1μ bar
Voltage response (VR) = + 1.6 dB ref. $1V_{RMS}$/μ bar

July-October 1978

Source level (SL) = +117.2 dB ref. 1μ bar
Voltage response (VR) = + 2.0 dB ref. $1V_{RMS}$/μ bar

The change of sensitivity at the beginning of April was due to the slight damage to the transducer, the following change at the start of July was the result of a new transducer replacing the damaged one.

From the above figures a factor can be obtained to adjust the integrator conversion factor.

	Performance change	Correction
August 1977 - March 1978	0 dB	x 1.0
April 1978 - June 1978	-1 dB	x 1.26
July 1978 - October 1978	+1.1 db	x 0.78

3.3 SURVEY METHOD

The choice of the acoustic method for the pelagic survey was made because it is believed to be the fastest method of assessing the distribution and magnitude of pelagic stocks of small species.

The distribution and magnitude of small pelagic fish stocks may vary considerably throughout the year. In order to determine these variations, seasonal coverages were carried o[ut]. To reduce the variation within a season, each coverage must be completed in as short a time as possible. Each coverage was divided into three cruises, and had to be completed rapidly with only a short break between the three cruises.

In the present survey, each coverage lasted 2 1/2 months and the project area was subdivided as follows, to be covered in three cruises (FAO, in press).

Statistical Area I -	Northwestern gulf:	The Gulf from its northern end to Qatar
Statistical Area II -	Southeastern gulf:	From Qatar to the Strait of Hormuz
Statistical Area III -	Gulf of Oman:	From the Strait of Hormuz to the Iran-Pakistan border, and Ras el Hadd

3.3.1 Collection of Data

3.3.1.1 Acoustic data

Acoustic data were collected while the vessel was steaming along a predetermined track. The survey track pattern for the acoustic survey was designed to fulfil the requirements of a complete coverage of the area in 2 1/2 months. A systematic cruise track was used for the three coverages (Figs. 3.1, 3,2 and 3.3). The spacing between adjacent legs was chosen to be 20 n.mi. This was selected as a compromise between the required detail of the coverage and the available time for the area. In the Gulf a rectangular track was used to give a uniform coverage whereas in the Gulf of Oman, due to the narrow continental shelf, a sawtoothed pattern was adopted. In the latter area, short track legs were extended beyond the edge of the shelf, and longer legs were used to cover the centre of this area.

The acoustic survey equipment, sounder, integrator and sonar were operated continuously along the survey track. A reading was recorded after completion of each nautical mile. At the same time, the sonar and sounder paper was annotated for later analysis. Problems in reading sonar recordings were experienced, because of the presence of strong temperature gradients, and the fact that in the shallow waters, where most of the fish was distributed, it was difficult to separate echoes of the bottom from those of fish schools. In addition, the survey work was performed continuously both during day and night, and there were no sonar recordings during the night, since the fish were spread out. In view of this, the work was concentrated on the analysis of the echo-integrator data. Each value read from the echo integrator is proportional to the average density of fish in each mile steamed. The ship's log provided a signal once every nautical mile, which was used to mark the sounder paper and reset the echo-integrator.

3.3.1.2 Biological data

Fishing operations were carried out during the survey (Fig. 3.4) to identify the species present and to determine their relative proportions in areas where they appear mixed. Fish length measurements were made from each sample. Purse seine fishing was carried out by LEMURU and MAJID mainly during the day and the midwater trawl was used only by LEMURU for sampling at night. On other occasions, fish were concentrated at night using both surface and underwater light and captured using the purse seine.

Biological information on small species entering the trawl catches was also collected by project vessels working on the demersal survey in the area. This information and data from other available sources have also been taken into consideration in the present report.

3.3.1.3 Hydrographic data

During the whole survey, surface temperature readings were recorded, every nautical mile, from the sea water intake of the main engine water cooling system. Bathythermograph readings over the full depth range within the Gulf and to a maximum of 140 m in the Gulf of Oman were taken at pre-selected stations. At the same stations, water samples

from 0, 10, 30, 50, 75 and 100 m were taken to determine salinity. A full description of the results is presented in the separate report on environmental conditions in the Gulf and the Gulf of Oman (FAO, in preparation).

3.3.2 Data Processing Methods

3.3.2.1 Correction of integrator readings

The echosounder and integrator equipment provide a recording of the fish detections on the echosounder paper, and a value proportional to average fish density for each nautical mile of survey track. This value includes a series of detections on plankton, temperature effects, demersal species in midwater during the night, and occasionally the sea bed. To correct for these, it was necessary to examine carefully the echosounder readings, in relation with the output value of the echo-integrator and determine the value to be attributed to the small pelagic species. During summer, strong temperature gradients were detected by the sounder and contributed largely to the integrator readings. This effect was even increased in the shallow waters where very dense plankton layers appeared at night and seemed to follow the temperature stratifications. This phenomenon could give very high integrator readings and it was difficult to decide which part belonged to the fish and which belonged to the plankton and the temperature effects. On many occasions the midwater trawl was shot on such very dense layers and either nothing or only jellyfish were caught. The decision to attribute a value corresponding to the fish only was based on the experience gained in the area, in reading echosounder detections, and using the sampling catches. The effect of the thermocline and the plankton was nearly negligible during the cold season. At night, the part of the integrator value due to the demersal species was deducted on the basis of the catch composition assuming that all species had similar acoustic properties. In the case of occasional sea-bed detections, "jumps" on the echo-integrator recordings could be easily identified and then excluded.

Occasionally, very dense pelagic schools close to the sea bed were identified by the integrator as sea bed, and therefore excluded from the recording as a result of a feature of the equipment which closes the sampling interval of the integrator as soon as a very strong echo, such as the one from the bottom is detected. If the echo-integrator indicated the presence of such schools, values for these were then determined on the basis of the values given by other schools in the neighbourhood, and added to the integrator reading.

3.3.2.2 Determination of constants for each species

The data obtained from the echo-integrator system are in the form of relative abundance figures. To ensure the standardization of the readings, a regular performance check is required. To convert the relative abundance figures into absolute abundance figures, a calibration of the equipment was carried out using live fish to determine the reflectivity properties of the fish species. A comparison factor for day and night variations was also determined.

(a) Acoustic/electrical performance check

Throughout the survey, series of performance checks were made during each cruise on the performance of the equipment to detect any small changes in the parameters of the sounder and the integrator system. These checks included electrical measurements carried out onboard and acoustic measurements using a hydrophone below the vessel. As a verification of the performance measurements, a standard target (ping pong ball), was hung below the transducer and the value of its target strength recorded.

The results of the overall performance checks are given in Table 3.1. The values given there were used to modify the integrator constant. This then takes into account the electro-acoustic performance changes in the equipment. There are three different values quoted at the end of Table 3.1 and those relevant were used for each of the periods shown.

(b) Calibration using live fish

Calibration experiments with live fish have been carried out by measuring the reflection of known quantities of fish contained in a cage suspended below the acoustic transducer. Both during the calibration and the survey the echo-integrator measures the echo from the fish contained in the echosounder beam. The dimensions of the water columns covered by the sonic beam, and its cross section area are known. This allows to convert integrator readings into quantity of fish under a unit of sea surface. The fish density is then expressed in $t/n.mi^2$ A full description of these experiments, carried out by LEMURU in February 1978, is included in Appendix 2.

(c) Day/night comparison

During the survey, marked differences in the behaviour of the fish between day and night were observed. In order to determine if these differences were affecting the abundance estimates, a series of day/night comparison experiments were carried out in July and October 1978.

A full description of these experiments and the results are given in Appendix 4. Substantially higher recordings were obtained for Sardinella sindensis (sind sardinella) during the night. Accordingly, all day observations should be raised by a day/night factor. Only for S. sindensis has a day/night compensation factor been determined. For Stolephorus sp. (anchovy) there were indications that little or no day/night differences occurred. For other species, the day/night compensation factor could not be determined, and hence no corrections have been applied. This may have led, if anything, to some underestimation of the fish abundance.

(d) Integrator constant for each species

In order to obtain an integrator constant for each species, the values obtained from live fish calibration, equipment performance tests, and day/night comparison experiments were combined. This gave a different constant for each species and in fact two constants for S. sindensis (one was applied to the night readings and the other to the day readings).

$$C_{(\text{species i})} = C_{(\text{equipment})} \times C_{(\text{fish experiment})} \times C_{(D/N)}$$

where

C (species i) is the constant for species 'i'

C (equipment) is the value to compensate for equipment performance

C (fish experiments i) is the value from the live fish calibration experiments for species 'i'

C (D/N) is the value to compensate for day/night variations

Thus, an integrator conversation factor ($t/n.mi^2/mm$ ref. 1 n.mi) is generated for each species and each condition (Appendix 3).

3.3.2.3 Species composition

Because different species have different integrator constants and the species may occur mixed, the integrator values have to be split by species. In order to determine the species composition, traces seen on the echosounder were sampled using a purse seine or a midwater trawl. The results of all fishing operations by LEMURU (Fig. 3.4) and those carried out by MAJID, 4 in the northwestern Gulf and 20 in the southeastern Gulf, were used to determine within each survey the proportion of the different species. In the case of small sized fish, such as *Stolephorus* sp., the proportion caught in the midwater trawl was not representative due to the 20 mm mesh size of the cod-end. This was taken into account. Subareas of similar species compositions were identified for cach cruise, and for each of these subareas an integrator constant, taking into account the different values for each species, weighted by their proportions, was calculated and applied to the integrator readings to obtain absolute density figures as follows.

$$\rho_B = \frac{M}{\frac{R_a}{C_a} + \frac{R_b}{C_b} + \frac{R_c}{C_c} \dots + \frac{R_i}{C_i}}$$

where ρ_B = Biomass density ($t/n.mi^2$)

M = Integrator reading (mm)

C_i = Integrator conversion constant for species 'i'

R_i = Proportion of species 'i'

3.3.2.4 Abundance and distribution maps

The equipment provides a relative density value every nautical mile. In order to smoothen the variation between consecutive miles and to make the data more manageable, five-mile averages were calculated. These figures were then transformed into absolute density values ($t/n.m^2$), by applying the appropriate constants as described in section 3.2.2.

The absolute density figures were plotted on a chart. Subareas with densities from 10 to 100 and 100 to 1 000 $t/n.mi^2$ were identified and their surface area measured. This assumed that the density values collected along the survey track are representative of the fish density in an area of 10 miles on each side of the track. Average densities for each subarea were calculated and multiplied by corresponding surface areas to obtain the total biomass.

$$W_B = \sum_{i=i}^{n} A_i \times \rho_i$$

where W_B = total biomass estimate tons

A_i = surface area (area i) $n.mi^2$

ρ_i = mean density (area i) $t/n.mi^2$

3.4 RESULTS

3.4.1 Integrator Conversion Constant and Day/night Correction Factor

The live fish calibration experiment (see Appendix 2) and the day/night comparison experiment (see Appendix 3) provided information on area back-scattering strength for

Sardinella sindensis and a mixture of 45 percent Decapterus kiliche and 55 percent of Selar crumenophthalmus and resultant conversion constants for integrator readings, as well as the correction factors for day-time integrator readings (Tables 3.1 and 3.2).

Since the calibration experiment was undertaken only with the above-mentioned species, conversion constants and area back-scattering strength values for other species in the Gulfs had to be assumed for the purpose of this survey. The values obtained from the mixture of small Carangidae were considered as valid for other small Carangidae and Rastrelliger sp., on the assumption that this group of species would have similar acoustic properties. On the same basis, the values obtained for S. sindensis were used for all the other species of clupeoids. These values were again taken for Stolephorus sp. and the Myctophidae, but compensated for their smaller length, since the experiment was done on 10.6 cm average size S. sindensis.

3.4.2 Species Observed

The acoustic survey was concerned with the stock of small pelagic species, including Myctophidae. For the purpose of this report, the denomination "small pelagics" will be used for all the species of small pelagic fish excluding the Myctophidae (lanternfish) and other mesopelagic fish. The denomination Myctophidae will be used for the latter.

Table 3.2

AREA BACK-SCATTERING STRENGTH AND INTEGRATOR CONVERSION CONSTANTS

Species	Area Back-scattering Strength ($dB/kg/m^2$)	Integrator Conversion Constant ($t/n.mi^2/mm$ ref. to 1 $n.mi^2$)
Sardinella sindensis	-30	5.3
Mixture of 45% Decapterus kiliche 55% Selar crumenophthalmus	-28.8	4.0
Trachurus indicus 1/	-28.8	4.0
Rastrelliger kanagurta 1/	-28.8	4.0
Other Sardinella and Dussumieria species 1/	-30	5.3
Myctophidae (5.2 cm) 1/	-28.4	3.7
Stolephorus sp. (6 cm) 1/	-28.4	4.0

1/ Assumed values

Table 3.3

AVERAGE CORRECTION FACTOR FOR DAY-TIME INTEGRATOR READINGS

Sardinella sindensis and other Sardinella and Dussumieria sp.	1.80/1
Stolephorus sp.	None
Small Carangidae	Lack of sufficient information

These two groups consist of several species. The main species were:

Clupeidae:	Sardinella sindensis (Sind sardinella)
	Sardinella fimbriata (Fringescale sardinella)
	Sardinella longiceps (Indian oil sardinella)
	Ilisha melanostoma (Indian ilisha)
	Dussumieria acuta (Rainbow sardine)
	Nematalosa nasus (Bloch's gizzard-shad)
	Etrumeus sp. (Round herring)
Engraulidae:	Stolephorus sp. (Anchovy)
	Thryssa vitrirostris (orange mouth thryssa)
Carangidae:	Decapterus kiliche (Scad)
	Selar crumenophthalmus (Bigeye scad)
	Trachurus indicus (Horse mackerel)
Scombridae:	Rastrelliger kanagurta (Indian mackerel)
Myctophidae:	Benthosema pterotum (Lanternfish)
	Benthosema fibulatum (Lanternfish)

Among these species S. sindensis, D. acuta, Stolephorus sp. and B. pterotum constitute the main part of the pelagic stock of small species in the project area. The small Carangidae contribute also to the stocks of small pelagics but to a relatively smaller extent. Other groups of species, mainly Leiognathidae and Gerreidae which are demersal during the day, occur in midwater during the night. This has been taken into account, and the Leiognathidae and Gerreidae were considered as demersal species, and therefore excluded from the night integral along with any other demersal fish, for the purpose of estimating the magnitude of the stocks of small pelagics (see Section 3.3.2.1).

3.4.3 Abundance and Distribution of Small Pelagics and Myctophidae

Most of the results can be seen from the abundance and distribution maps (Figs. 3.5, 3.6 and 3.7). Table 3.2 gives the biomass estimates of small pelagics and Myctophidae by statistical area, and for each coverage. It can be seen from the distribution charts (Figs. 3.5, 3.6 and 3.7) that there were no fish concentrations in the deep water in the centre of the Gulf, which allowed a separate estimate for the Iranian and the Arabian side. In the case of the Gulf of Oman, the Myctophidae were distributed over the whole area and an arbitrary line through the centre of the Gulf of Oman was used to give estimates for the Arabian and Iranian sides. For the subareas in the Gulf, the proportion of the biomass for the three main groups of species - sardines, anchovies and small Carangidae calculated from the

Table 3.4

BIOMASS ESTIMATE OF SMALL PELAGIC FISH AND MYCTOPHIDAE IN THE GULF AND GULF OF OMAN ('000 t)

		SMALL PELAGIC FISH								MYCTOPHIDAE Gulf of Oman	
		Northwestern Gulf (Area I)		Southeastern Gulf (Area II)		Gulf of Oman (Area III)		Total Small pelagics			
		'000 t	%	'000 t	%	'000 t	%	'000 t	%	'000 t	%
	Time	Sept.	1977	Oct.	1977	Nov.	1977			Nov.	1977
First	Iranian side	170	14	124	11	57	5	351	30	2 000	44
Coverage	Arabian side	200	17	615	52	7	1	822	70	2 550	56
	Total	370	31	739	63	64	6	1 173	100	4 550	100
	Time	March	1978	April	1978	May	1978			May	1978
Second	Iranian side	13	5	69	27	17	7	99	39	1 035	36
Coverage	Arabian side	60	24	85	34	8	3	153	61	1 850	64
	Total	73	29	154	61	25	10	252	100	2 885	100
	Time	July	1978	August	1978	Sept.	1978			Sept.	1978
Third	Iranian side	386	22	560	32	15	1	961	55	440	26
Coverage	Arabian side	136	8	626	36	4	0.2	766	45	1 260	74
	Total	522	30	1 186	69	19	1	1 727	100	1 700	100

3.4.3.1 First coverage: September-November 1977

The first coverage was undertaken during the warm season, in terms of water condition (see report on environmental conditions (FAO, in preparation)). The total estimated abundance was 1 173 000 t of small pelagic fish in the whole project area and 4 550 000 t of Myctophidae in the Gulf of Oman. The fish distribution and abundance (Fig. 3.5, Tables 3.3 and 3.4) show that 70% of the biomass of small pelagics was concentrated on the Arabian side and 52% along the Arabian side of the Southeastern Gulf. Apart from the Gulf of Oman, where the small pelagics were not abundant, the lowest percentage of 11% was observed along the Iranian side of the southeastern Gulf. In the Gulf of Oman, 56% of the biomass of the Myctophidae were observed along the Arabian side.

3.4.3.2 Second coverage: March-May 1978

During the second coverage (Fig. 3.6, Tables 3.4 and 3.5), which took place in the cold season, the estimate obtained for total biomass of small pelagic fish in the project area was 252 000 t and 2 885 000 t of Myctophidae in the Gulf of Oman, indicating a market decrease compared to the first coverage. For the small pelagic fish, the difference in proportion between the Iranian (39%) and Arabian side (61%) became reduced. The highest proportion of the biomass (34%) was still observed along the Arabian side of the south-eastern Gulf and the lowest (5%) along the Iranian side of the northwestern Gulf. Though the southern part of the Gulf of Oman did not show a significant change in the estimate of small pelagic biomass between the first and the second coverages, that for the Iranian side of the Gulf of Oman declined by 70% during the second coverage. The proportion of Myctophidae in the Gulf of Oman was again greater on the Arabian (64%) than on the Iranian side (36%), and this difference was more significant than during the first coverage.

3.4.3.3 Third coverage: July-September 1978

This was undertaken during the warm season as was the first coverage. In earlier months (Fig. 3.7, Tables 3.4 and 3.5) the estimate of small pelagic fish in the project area was 1 727 000 t, reaching a higher level than during the first coverage. That for the Myctophidae in the Gulf of Oman was 1 700 000 t, which is the lowest estimate of all three coverages for these species.

During this coverage 55% of the total estimated biomass of small pelagic fish was observed on the Iranian side but 36% of the same biomass was again found on the Arabian side of the southeastern Gulf. The lowest proportion was this time on the Arabian side of the north-western Gulf (8%). There was a noticeable increase in the biomass estimate on the Iranian side of the southeastern Gulf, when compared with the two previous coverages. In the whole of the southeastern Gulf, the estimates were similar during the first and third coverages, 615 000 and 626 000 t respectively. However, the third coverage in the Gulf of Oman showed for the small pelagics a decline of 70% compared to the higher estimate obtained during the first coverage. Whereas the biomass of Myctophidae in the Gulf of Oman was the lowest observed, its proportion on the Arabian side was the highest (74%).

3.4.4 Seasonal Variation in Distribution and Species Composition

The three coverages were undertaken in the three areas during different times of the year as follows:

Area I, Northwestern Gulf - September 1977, March 1978, July 1978
Area II, Southeastern Gulf - October 1977, April 1978, August 1978
Area III, Gulf of Oman - November 1977, May 1978, September 1978

Table 3.5

BIOMASS ESTIMATE ('000 t) AND PERCENTAGE BY SPECIES OF SMALL PELAGIC FISH IN THE GULF

		NORTHWESTERN GULF (Area I)						SOUTHEASTERN GULF (Area II)					
		Iranian side		Arabian side		Total area		Iranian side		Arabian side		Total area	
		%	('000)	%	('000)	%	('000)	%	('000)	%	('000)	%	('000)
		September 1977						October 1977					
First Coverage	Sardine	79	134	66	132	72	266	41	51	100	615	90	666
	Stolephorus	10	17	17	33	14	50	25	6	-	-	1	6
	Small Carangidae	11	19	18	35	15	54	54	67	-	-	9	67
		March 1978						April 1978					
Second Coverage	Sardine	30	4	20	12	22	16	20	14	100	85	64	99
	Stolephorus	70	9	80	48	78	57	80	55	-	-	36	55
	Small Carangidae	-	-	-	-	-	-	-	-	-	-	-	-
		July 1978						August 1978					
Third Coverage	Sardine	80	309	68	92	77	402	12	66	100	626	58	692
	Stolephorus	20	77	32	44	23	120	88	494	-	-	42	494
	Small Carangidae	-	-	-	-	-	-	-	-	-	-	-	-

The hydrological observations (which are reported in FAO, in preparation) show that for the first and the third coverage the conditions correspond to the warm water season, and that the second coverage was undertaken during the cold water season. There were no significant changes in the seasonal factors during the course of any of the three-month periods, and the situation within each coverage can be considered as uniform.

For the purpose of comparing the biomass and the species composition between coverages, the information will be considered by area (see Figs. 3.5, 3.6 and 3.7 and Tables 3.4 and 3.5).

3.4.4.1 Northwestern Gulf (Area 1)

Sardine was found to be predominant in September and July, when the highest biomass was observed, and Stolephorus was predominant in March. In fact, the estimate of the sardine biomass significantly reduced during the cold season, from 266 000 t in September 1977 to 16 000 t in March 1978. At the same time, the estimated amount of Stolephorus showed little variation with 50 000 and 57 000 t respectively for the two seasons. In July 1978 there was a general increase in the fish biomass, as in the other areas of the Gulf, the sardine biomass estimate reached 402 000 t, showing a 51% increase compared to September 1977, and the Stolephorus biomass estimate reached 120 000 t, showing a 140% increase compared to September 1977 and 111% compared to March 1978. The small Carangidae were found in midwater only during September 1977 and they were more abundant on the Arabian side.

The Stolephorus biomass estimate was lower on the Iranian side of the area during September 1977 and March 1978 as compared to the Arabian side. In July 1978, the situation was the reverse, due to a substantial increase of the Stolephorus biomass on the Iranian side. Sardines were equally abundant on either side of the area in September 1977 and more abundant on the Iranian side in July 1978. During March 1978 hardly any sardine were observed on either side.

In all coverages Sardinella sindensis was predominant on the Arabian side, while Dussumieria acuta was predominant on the Iranian side.

3.4.4.2 Southeastern Gulf (Area 2)

Sardine was again predominant during the warm season in October 1977 and August 1978, with estimates of 666 000 t and 692 000 t respectively, as compared to 99 000 t in April 1978. Stolephorus was much more abundant in August 1978 (494 000 t) than in October 1977 (6 000 t) and April 1978 (55 000 t). Small Carangidae were found only in October 1977. The increase in the estimate of total biomass in August 1978 was due to the increase in the quantity of Stolephorus, this being mainly on the Iranian side of the area. During the three surveys the Arabian side was found to be populated almost exclusively with sardines, mainly S. sindensis with some S. fimbriata and S. longiceps. On the Iranian side D. acuta was predominant, mixed with S. sindensis. More than 85% of the sardine population was observed in the Arabian side of the area, during the three surveys. The Stolephorus were found only on the Iranian side of the area; their proportion on the Arabian side was observed to be negligible.

3.4.4.3 Gulf of Oman (Area 3)

The majority of the fish population in this area was constituted of Myctophidae and mainly Benthosema pterotum. The estimated abundance of Myctophidae was highest in November 1977 (4 550 000), lower in September 1977 with 1 700 000 t. The abundance was higher on the

Arabian side as compared to the Iranian side during the three prospections. The biggest difference was observed in September 1978 (74% on the Arabian side).

Other small pelagics such as sardines and anchovy, were present in small quantities, and localized in small areas close to the shore. The estimated abundance was higher in November 1977 with 64 000 t, and decreased in May 1978 to 25 000 t, and then in September 1978 to 19 000 t. Small pelagic fish have been observed regularly in the western end of the Gulf of Oman, on the Iranian side close to the Strait of Hormuz, where *S. sindensis*, *D. acuta*, *Stolephorus* sp. and *Thryssa vitrirostris* were identified. On the Arabian side, west of Muscat, *D. acuta*, *S. sindensis* and *S. longiceps*, *Stolephorus* sp. and small Carangidae were observed.

3.4.5 Biological Results

3.4.5.1 Bathymetric distribution and behaviour

The majority of the sardine schools were observed in waters shallower than 40 m. They were distributed from the bottom to the surface during the day, in high and narrow dense schools. The school size determined from the sampling catches ranged from 0.5 to 10 t, and the average size was 2.5 t. During the day, the majority of the detections were of schools 50-200 m apart, sometimes less, aggregated in clusters. At dawn and dusk sardine schools were often seen on the surface. During the night, the schools spread out into a homogeneous layer of fish throughout the whole depth range. When in schools, sardines are very active and they quickly react to the boat or the fishing gear.

Stolephorus were also observed in schools during the day and in layers of dispersed fish during the night. *Stolephorus* schools are smaller than sardine schools and less active; it was possible to catch them with a midwater trawl during the day. Day schools have a tendency to group together and form a layer of schools following the same depth. *Stolephorus* were also found mainly in waters shallower then 40 m. No school size data are available since the mesh size of all the fishing gear were too big for this species.

Small Carangidae were caught mainly during the night time, by midwater trawl. They were generally mixed with sardines and *Stolephorus*, contributing to form a layer of mixed fish at night. However, the small Carangidae have a tendency to be distributed in the lower part of the layer. During the day, they appear as small schools, often touching the bottom and generally not higher than a metre or two. Their distribution seems to be slightly deeper than the sardines and *Stolephorus* as they were also observed beyond the 40 m isobath.

In the Gulf of Oman, Myctophids were distributed beyond the 150 m isobath. They appeared in two layers during the day. The upper one, between 150 and 200 m depth, was composed of dense schools aggregated together, the lower one at a depth between 250 and 300 m appeared to be more diffuse. The two layers were migrating towards the surface just before sunset for feeding; they sank again a little before sunrise. During the night the two layers were mixed together between 10 and 50 m. According to Gjøsaeter (1977) there is no difference in the composition of the two layers. Another more diffuse layer, unidentified, was sometimes observed at about 400 m depth, remaining at the same depth during day and night.

3.4.5.2 Biological information by species

(a) Sardinella sindensis (Sind sardinella)

The size range (Sind sardinella) found in the Gulf and the Gulf of Oman, was from 5 to 19 cm. Length frequency distribution of the sampling made during the acoustic survey, including those of the preliminary phase and samples from MAJID and the demersal survey, are given by month in Fig. 3.8. Observations on sexual maturity, from the Ras Al Khaimah Fishing Company (see part 4) showed a spawning season from the middle of May until the end of June in 1977. According to observations made during the survey, the spawning season appeared to be from the middle of April until the end of May. During this period the average length of the fish observed was between 11 and 15 cm in the southeastern Gulf, depending on the year. Fish samples caught in October and November, ranging in size from 9 to 14 cm with an average total length of 11.5 cm, sent to the Marine Laboratory in Aberdeen for tentative ageing, did not show evidence of a growth ring. Small fish of 5-8 cm begin to appear from June; this could indicate a rapid growth rate in the young stages. Fishes from 15 to 18 cm were only observed from December to May in the southeastern Gulf; they were not seen later. In the Gulf of Oman they were still present in June 1977.

Length-weight relationship obtained from two samples immediately after catch were as follows:

Northwestern Gulf, June 1977: $W = 0.0077\ L^{3.050}$ for the range of 11 to 14 cm with a correlation coefficient of 0.92.

Southeastern Gulf, February 1978: $W = 0.0027\ L^{3.421}$ for the range of 8.5 to 12 cm with a correlation coefficient of 0.89.

Before and during the spawning season the sex ratio in the samples showed a higher percentage of females, which varied between 50-80%. During the rest of the year, most of the stock was immature and the sex ratio could not be determined.

(b) Sardinella fimbriata (Fringescale sardinella)

This species was not caught regularly enough to give significant information. The average size observed varied between 9 to 11.5 cm according to the season and area and the size range was from 7 to 14 cm. The average individual weight was 13.74 g for fish of 11.4 cm and 5.56 g for fish of 9.3 cm. The sex ratio observed in one sample in April 1978 was: 67% females and 33% males.

(c) Sardinella longiceps (Indian oil sardinella)

Little information was also collected on this species. The size ranged from 8 to 21 cm and the average size varied between 10.5 to 17 cm according to area and season. This species appears to be more frequent in the easternmost part of the southeastern Gulf and in the Gulf of Oman. The northern limit of its distribution seems to be somewhere close to the middle of the Gulf.

(d) Ilisha melanostoma (Indian ilisha)

This species was found only on the Iranian side of the Gulf. The size ranged from 12 to 29 cm showing two modes at 16 and 24 cm in October 1977, and one mode at 26 cm in August 1978.

(e) Etrumeus sp. (Round herring)

A few observations were made of the species in the Dubai area. The size ranged from 16 to 20 cm and in February-March all the individuals were fully mature or spawning.

(f) Dussumieria acuta (Rainbow sardine)

This species was more regularly observed on the Iranian side of the Gulf. Figure 9 shows the size range and mode of all the samples collected. The maximum size observed was 21 cm and the minimum 6 cm. According to the Ras al Khaimah Fishing Company (see part 4), the spawning period takes place in April-May, with a possible second one in November. The small fish of 6 cm first appeared in July to September. The biggest fish up to 21 cm were present in April-May. The sex ratio was 50% males, 50% females.

(g) Thryssa vitrirostris (Orange mouth thryssa)

This species was observed very occasionally, and only two samples could be taken. One in June 1977 near Kuwait gave a size range of 12 to 18 cm with an average length of 14.39 cm. The second one, in May 1973, in the Strait of Hormuz, gave a size range from 7 to 10 cm with an average length of 8.67 cm.

(h) Stolephorus sp. (Anchovies)

Several samples have been collected. The mesh size of the sampling gear was too big to obtain a representative sample for length frequencies. However, a size range from 3 to 11 cm was recorded. Species identification was not possible due to lack of documentation.

(i) Rastrelliger kanagurta (Indian mackerel)

Indian mackerel was often caught in small quantities during the pelagic survey. Fig. 3.10 gives the size range and modal size of all the samples collected, including the demersal survey samples from various substrata. The size ranged from 7 to 25 cm. The smallest fish were observed in July and the biggest in April. The females were found ripe from April to June.

(j) Trachurus indicus (Indian horse mackerel)

All samples of T. indicus from both the demersal and pelagic survey have been included in Fig. 3.11, which gives the size range and modal size of each sample. The smallest fish observed (5-6 cm) occur in May. From May until August two modes seem to be present: between 9-14 and between 14 and 19 cm. The biggest fish (23 cm) were observed in December. Ripe females were observed from March until May.

(k) Decapterus kiliche (Kiliche scad)

This is the most common of the small Carangidae. Size range and modal size are given in Fig. 3.12. The smallest fish (5 cm) were present in July, and the biggest in September and also August. Growth trends are difficult to identify, but there is a group of small fish from 8 to 14 cm present from July to February, and another group from 14 to 20 cm present from February to July. Ripe females were observed in April and July.

(l) Selar crumenophthalmus (Bigeye scad)

The size of this species ranges from 7 to 30 cm. Catches during the pelagic survey have always been small, and the number of samples is insufficient to draw conclusions. Ripe females have been observed in June. The samples of small Carangidae from the demersal survey were sporadic in respect to the season and area of collection.

(m) Myctophidae (Lanternfishes)

Two species were observed: Benthosema pterotum and B. fibulatum. For B. pterotum, during May 1978 the average size was 42 mm and the range from 35 to 49 mm. In September 1978 the average on the Oman side was 44.5 mm and the range from 35 to 54 mm while on the Iranian side the average was 30.1 mm and the range from 10 to 60 mm.

For B. fibulatum, in May 1978 the average length was 57.8 mm and the range 46-65 mm. Samples of Myctophidae sent to the University of Bergen, Norway, have been identified and analysed by J. Gjøsaeter. In May 1978, about 90% of the specimens of B. pterotum were females and most of these were ripe or spawning. Most of the stomachs were full, with copepods and euphausiids. In the case of B. fibulatum, the sexes were about equally abundant and most of the fishes were maturing; none were ripe. In the samples collected in September 1978, only B. pterotum was represented, again copepods and euphausids along with fish eggs were identified in the stomachs. The adult fishes were in pre-spawning or spawning condition.

3.5 DISCUSSIONS AND CONCLUSIONS

For safety reasons and due to the presence of many fish traps and drift-nets, the survey vessel could not survey the very shallow waters. The acoustic survey was therefore limited to the area bordered by a line that approximately corresponded to the 10 m isobath. Due to these operational difficulties, a total area of 20 440 n.mi^2, which is 20 percent of the total project area, was not surveyed. Of the non-prospected area, 70 percent lies on the Arabian side of the Gulf.

Within the depth range of 10 to 100 m in the Gulf, the survey results indicated that the main concentration of small pelagics appeared to be in the range of 10-40 m. However, there may have been some fish concentrations in the waters shallower than 10 m, and this would, if anything, lead to an underestimation of the biomass of small pelagics in the Gulf. Figs. 3.5, 3.6 and 3.7 show that on the Arabian side of the southeastern Gulf, the area up to the 20-fathom line is bigger than anywhere else in the Gulfs, and this area corresponds to the biggest biomass of small pelagics.

In the Gulf of Oman, the corresponding area is very small, and the biomass of small pelagics is also very small. There was relatively no small pelagic fish in the middle part of the Gulf except for concentrations of small Carangidae. In the Gulf of Oman, the central part was occupied by the Myctophidae.

The three estimates of the biomass of Myctophidae of respectively 4.5, 2.9 and 1.7 million t for the three seasonal coverages are smaller than the average estimation of 13 million t, found in the same area by the R/V DR FRIDTJOF NANSEN, over the period February 1975 to November 1976 (Gjøsaeter, 1977). Besides natural annual or seasonal variation in the abundance, this discrepancy could be due to the fact that in both cases no

back-scattering strength measurements on these species have been undertaken, and the conversion constant was derived from various small pelagic fish values and compensated for the smaller length (Gjøsaeter, personal communication). Therefore depending on the initial value chosen for the extrapolation, the conversion constant for the Myctophidae can differ and lead to different estimates. In view of this, these estimates should be considered as provisional until further experiments on back-scattering strength will be performed.

For the small pelagics (small pelagic species excluding the Myctophidae), the total biomass estimate in the project area showed a market drop during the second coverage, in the cold season (252 000 t) compared to the first (1 173 000 t) and third coverage (1 727 000 t), both undertaken during the warm season. The upper layer corresponding to the first 6 m of water was not sampled by the echosounder. However, sonar contacts and visual observations indicated the presence of fish in this water layer. These figures are then likely to be underestimated and unfortunately the bad sonar conditions could not permit judgement of the magnitude of this underestimation. In all coverages, the highest proportion of 60 to 70 percent of the biomass was observed in the northwestern Gulf (Area I). Sardines were always predominant on the Arabian side of the southeastern Gulf, even when the low estimate was obtained during the second coverage in April 1978. They were found on both sides of the northwestern Gulf (Area I) except during the second coverage in March 1978 when they had almost disappeared from this area, and they were predominant on the Arabian side of the same area during the third coverage in July 1978. Stolephorus showed a marked increase in proportion in the Gulf during the third coverage and mainly on the Iranian side.

The variations observed in the biomass estimates of the small pelagics could be due to several causes: changes in equipment performance; human errors in the processing of the data; changes in behaviour according to seasons, such as migration out of the area or out of the range of the sounder, in shallow waters or concentration on the bottom for spawning; regular seasonal or occasional variation in the biomass.

Performance checks have been conducted regularly, changes in equipment performances have been taken into account (see Appendix 2) and the integrator conversion factor corrected accordingly.

The human factor was certainly very important in the processing of the data, mainly during the correction of the integrator readings to eliminate that part which was caused by targets other than fish (Section 3.3.2.1). This operation was in fact easier during the cold season since hardly any temperature effect and plankton echoes had to be deducted from the readings. The possibility of an excessive correction was then not possible during the cold season. During the warm season a substantial part of the integrator reading had to be deducted to account for the temperature and plankton detections. The higher biomass estimates during the warm season could not be the result of an insufficient correction of the readings, because in the case of schools only the "jumps" in the echo-integrator recordings were taken into account.

The behaviour of the fish may have changed according to seasons. The possibility of the fish being distributed in the very shallow waters during the cold season was investigated in the area from Ras Al Khaimah to Dubai in February 1979. The results were considered to be negative unless the sardines had been really close to the beach in 2 or 3 m of water, which could not be checked. There is still the possibility that the situation during the survey in the 1978 winter was different from that in 1979. There are indications from the demersal

survey data that during the cold months sardine appeared in small quantities in the bottom trawl catches. During winter 1977, trawlers from the Ras Al Khaimah Fishing Company were catching up to 5 t of sardines in very shallow waters in that area. There is also evidence of movements of the sardines towards the terminal part of the Gulf of Oman and the Strait of Hormuz as reported in the New Hope Survey results (Fibiger and Frederiksen, 1957) and in the Bandar Abbas Canning Factory records (Rostami,1960). In this area the fishing season lasts from November to the end of April or the middle of May.

From the Ras Al Khaimah Fishing Company results (see part 4), it can also be seen that the best catches per boat were obtained from March to May but the Sardinella longiceps appeared to be more abundant from March to August and S. sindensis from the end of August to November. The spawning period for S. sindensis is mid-April to mid-June, and this corresponds to the low abundance estimate. The distribution observed in March 1971 (White and Barwani, 1971) on the Arabian side of the southeastern Gulf was similar to the one found in April 1978 with two major concentrations, one around Halul Island and a second one in the region of Dubai/ Ras Al Khaimah. During the cold season some fish may also have been very scattered over a large area, giving integrator readings close to zero. These low values would not have been taken into account when judging, if there was no evidence of the presence of fish on the echosounder recording paper. In any case, this would have contributed to a very small extent to the total fish biomass.

Large real seasonal variations in the biomass could occur in the case of a lifespan of one year with most of the fish dying after spawning. But there are indications that most of the species involved live longer. However, the variation in the biomass estimate in winter 1978 could have reflected a real, unusual change in abundance as a result of natural factors. For example, that year registered a low rainfall compared with 1977. In May (1977) which is in the transition period between the cold and warm season, a preliminary survey on the Arabian side of the southeastern Gulf gave a tentative biomass estimate of 600 000 t (see part 2). This is in the region of the two biomass estimates for the same area obtained in October 1977 (739 000 t) and in August 1978 (626 000 t). The results of the indicative fishing cruises conducted in the southeastern Gulf in February and March 1979 did not show strong evidence of a decrease in abundance.

In March 1977 a cruise was made in the Arabian side of the southeastern Gulf. While the echosounder was used with different settings, the integrator was not operated as no specialists in acoustics were available at that time. However, the distribution and subjective abundance estimation made from this cruise, when compared with the results of other cruises during the main survey in the same area, did not indicate a significant drop in abundance during that month.

If all these considerations are taken together, it would seem that the large difference between the summer and winter estimates from the survey do not reflect a real regular large fluctuation in the biomass of small pelagic fish. Whereas there are indications that at least a part of the differences found may have been due to normal seasonal changes in fish behaviour and distribution, the greater part of the big differences is still unexplained and may, partly or wholly, have been due to a real, unusual absence of fish from the region, whereas also the normal statistical error in each of the estimates may have played a role. In view of this, for the purpose of the determination of the potential yield, and in the absence of further information, the average biomass estimate of small pelagics excluding the Myctophidae was calculated by taking the average of the two high estimates obtained during the warm season and averaging the result with the low estimate obtained for the cold season.

The potential yield of a fish stock depends on its abundance, and on the biological characteristics of the species such as natural mortality. In the case of the small pelagics in the Gulfs, which are short-living fish, the proportion of the stock that can be harvested every year without damaging the stock is larger than for long-living species. An approximation of the potential yield of a fish stock is given by the equation:

$$Y = 0.5 \times M \times B_o$$

Where Y is the potential yield

M is the instantaneous natural mortality rate of the species

B_o is the unexploited stock biomass.

In the project area, the estimated present fishing mortality on the small pelagic species is small enough to make it possible to consider the pelagic stocks as virgin, and use the average biomass estimates of the survey as the unexploited stock biomass B_o. Considering that most of the small pelagic fish (sardines, Stolephorus, small Carangidae) are short-living species, the natural mortality rate must be high. Since knowledge on these species is limited, the potential yield will be calculated on the basis of an instantaneous mortality rate M ranging from 0.8 to 1. This would result in a lifespan of 2-3 years, which may be a reasonable assumption for the average of the mixture of species in the area. and in agreement with the data given in Holt (1960) and Nair (1960).

Although for some species this figure may be too high, in the case of the Myctophidae the biological knowledge is even more limited. However, there are indications that the life-span of these species could be one year or shorter (Gjøsaeter, 1977). For such a short-living species, the above equation for calculating potential yield may not be valid and, provisionally, a potential yield of half of the average biomass has been assumed. This stock is definitely a virgin stock since there is no fishery on the Myctophidae. The unexploited stock biomass figure used in this case will be the average of the three available estimates which did not show a large seasonal variation. This average of 3 045 million t would then give a potential yield of around 1.5 million t of Myctophidae.

The estimated potential yield for the small pelagics calculated with the above formula is around 400 000 t and about 60 percent of this corresponds to the sardines. Table 3.6 below gives the details by areas and for the two values of instantaneous mortality chosen.

Table 3.6

ESTIMATED POTENTIAL YIELD OF SMALL PELAGIC FISH, EXCLUDING MYCTOPHIDAE,IN THE GULF

		Northwestern Gulf Area 1	Southeastern Gulf Area 2	Gulf of Oman Area 3	Total project area
Average unexploited stock biomass ('000 t)		259	558	33	851
Estimated potential yield ('000 t)	M = 0.8	104	223	13	340
('000 t)	M = 1.0	130	279	17	426

It should be stressed that all these potential yield estimates are very tentative, and that they should be taken as a rough indication of the order of magnitude of the potential. The potential yield of small pelagics is given by areas to provide an indication of its repartition, but it must be remembered that these fish are likely to undertake migrations from one of the areas distinguished here into another. The potential yield of a stock could, in principle, be taken in any part of its area of distribution. This makes it difficult to define potential yield by areas as long as the information on stock separation and migration is insufficient. In addition, the biomass estimates were made in a particular year and substantial variations are likely to be observed as a result of changes in fish abundance related with environmental conditions. These variations can only be determined by further information. This should be taken into account in any evaluation of the results of the present studies.

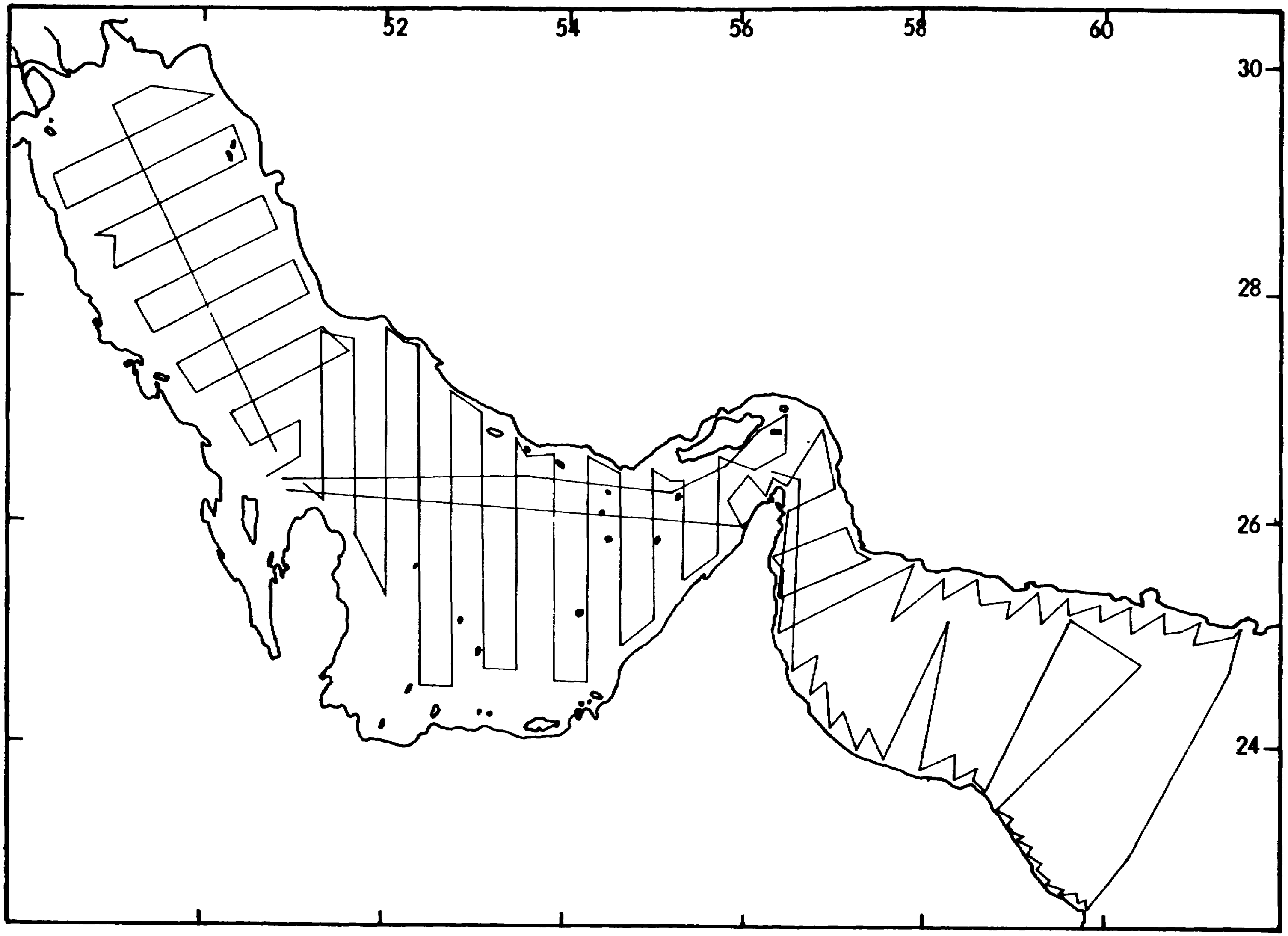


Fig. 3.1 - Survey track,first coverage September-November 1978

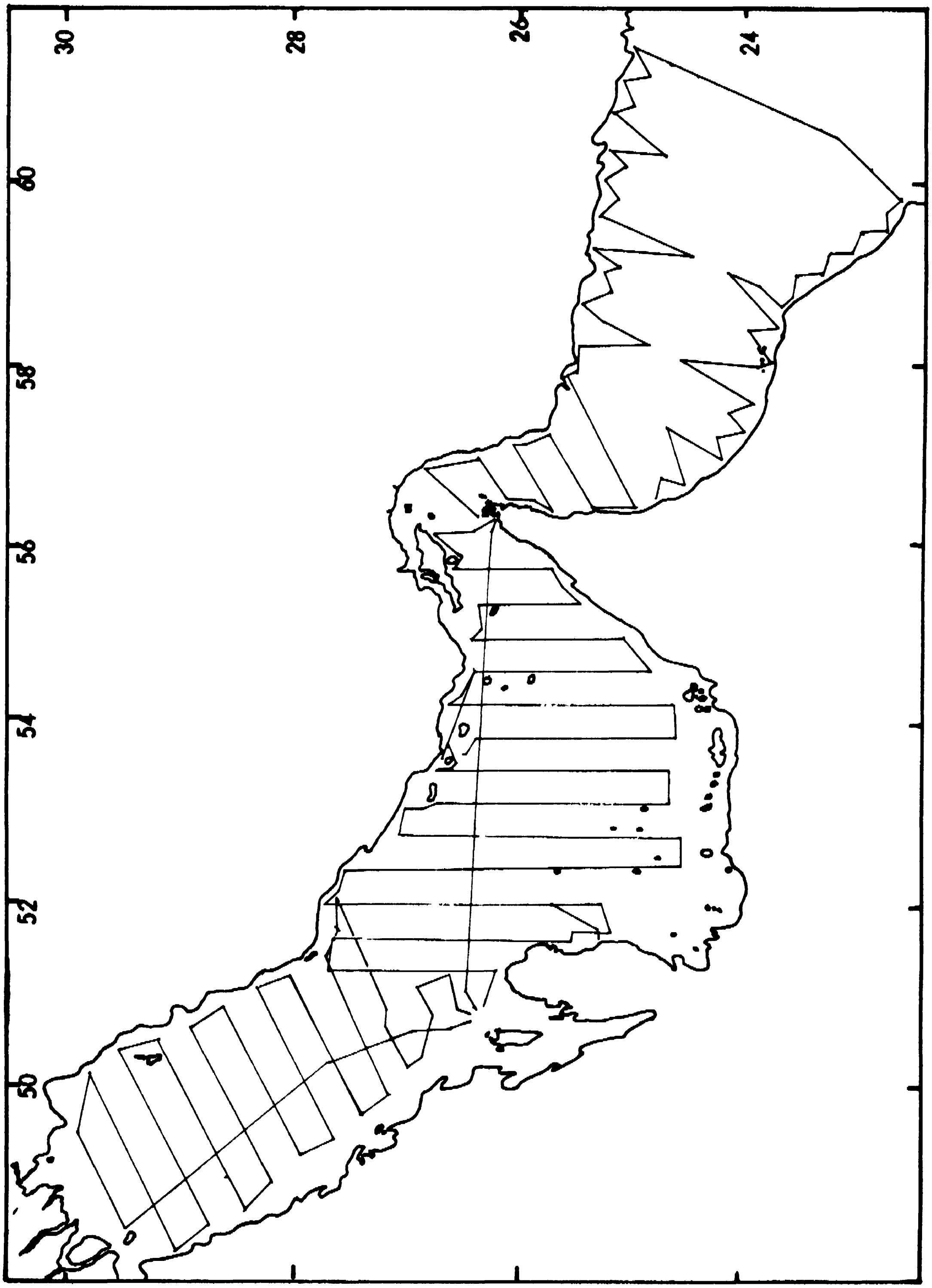


Fig. 3.2 - Survey track, second coverage March-May 1978

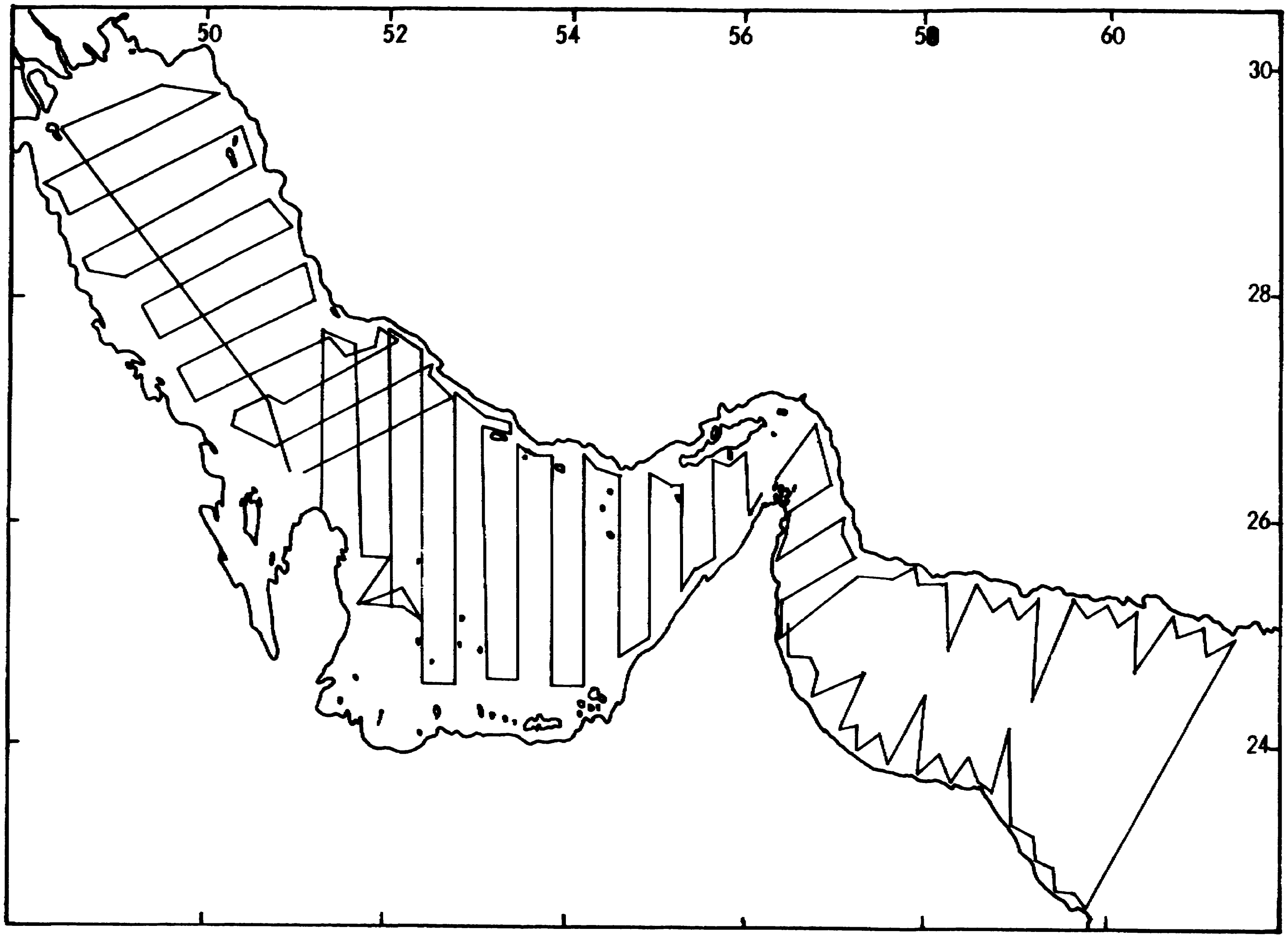


Fig. 3.3 - Survey track, third coverage July-September 1978

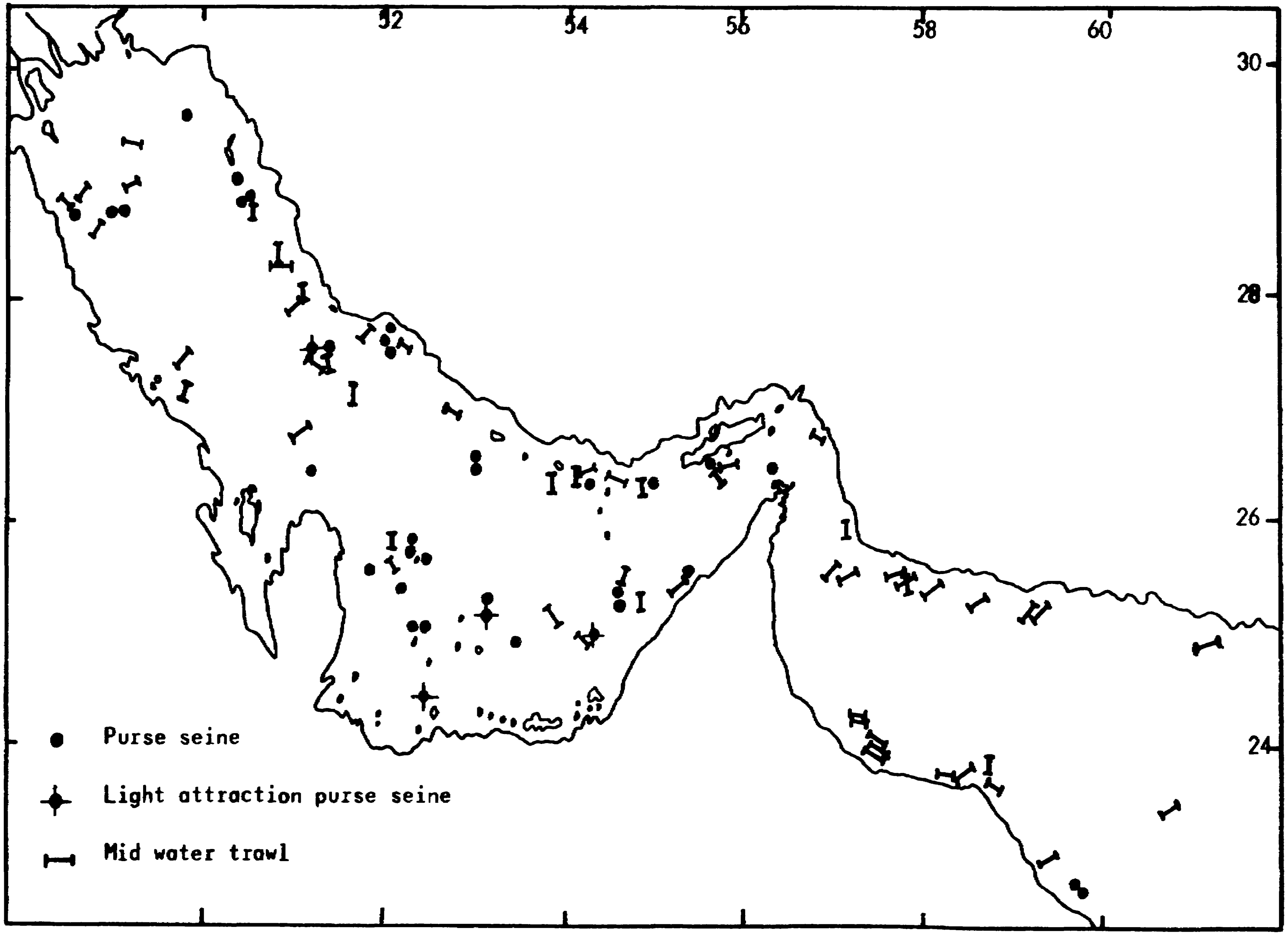


Fig. 3.4 - Fishing operation

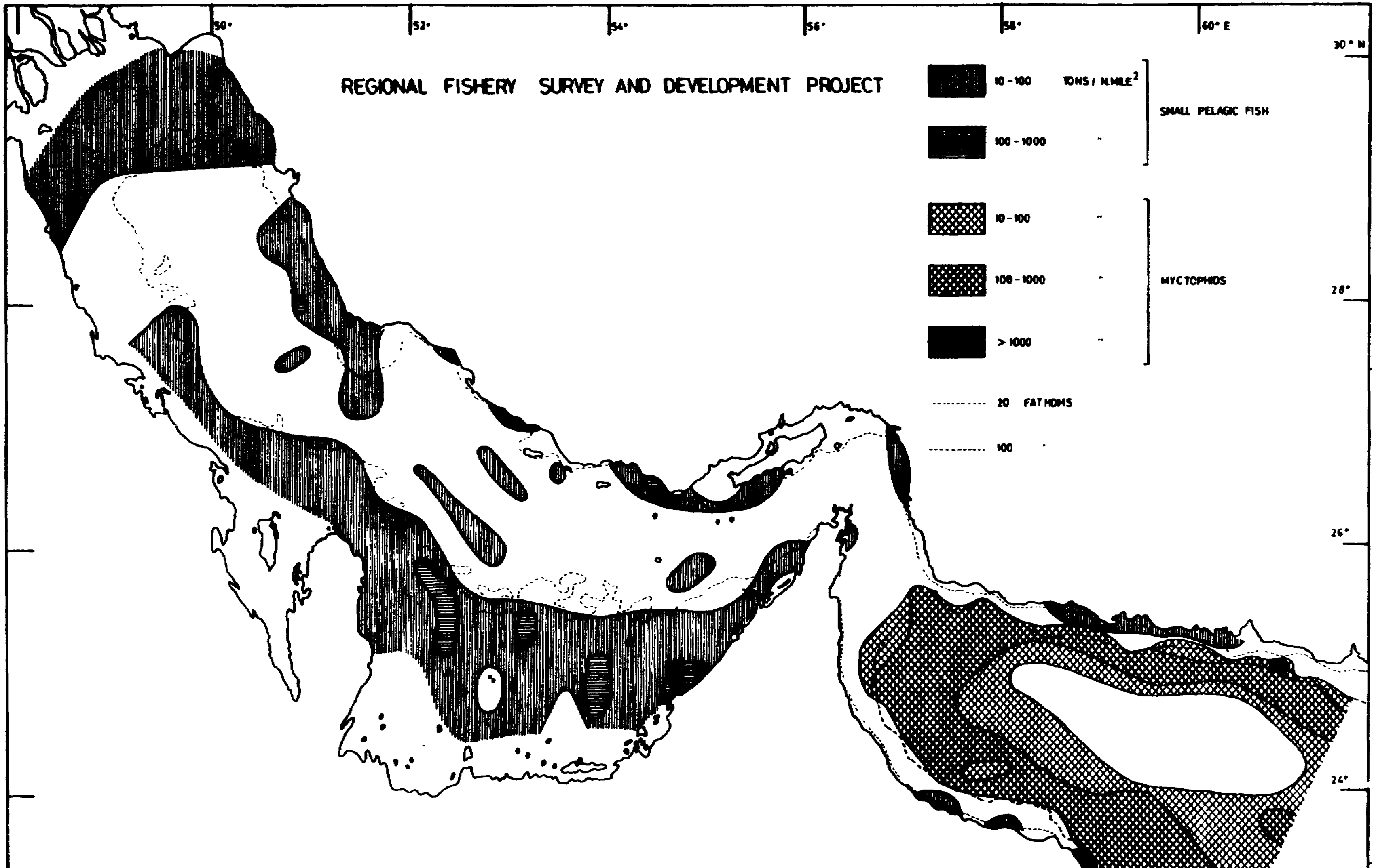


Fig. 3.5 - ABUNDANCE AND DISTRIBUTION OF SMALL PELAGIC FISH AND MYCTOPHIDS

FIRST COVERAGE SEPTEMBER - NOVEMBER 1977

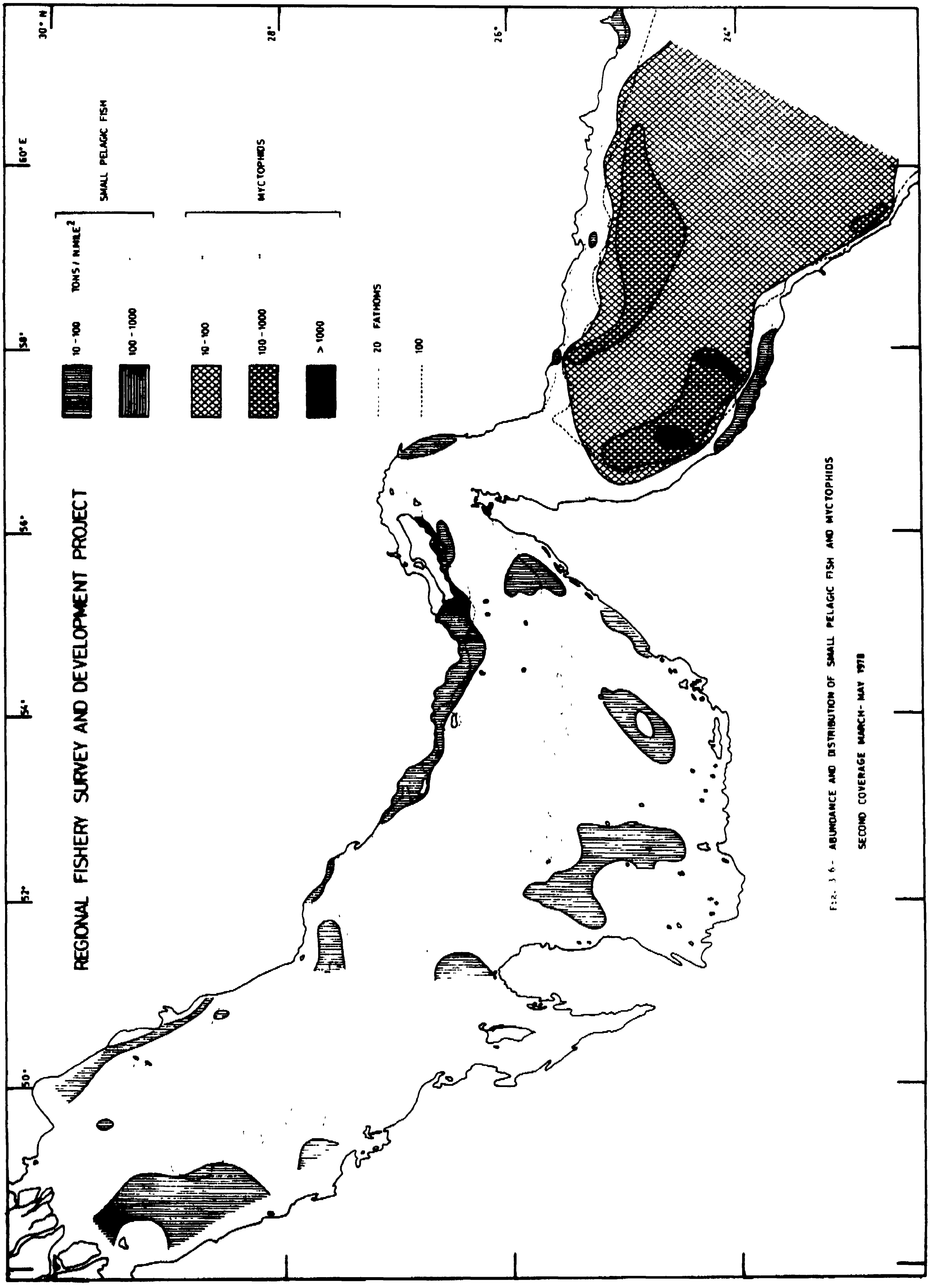


Fig. 3.6 - ABUNDANCE AND DISTRIBUTION OF SMALL PELAGIC FISH AND MYCTOPHIDS
SECOND COVERAGE MARCH- MAY 1978

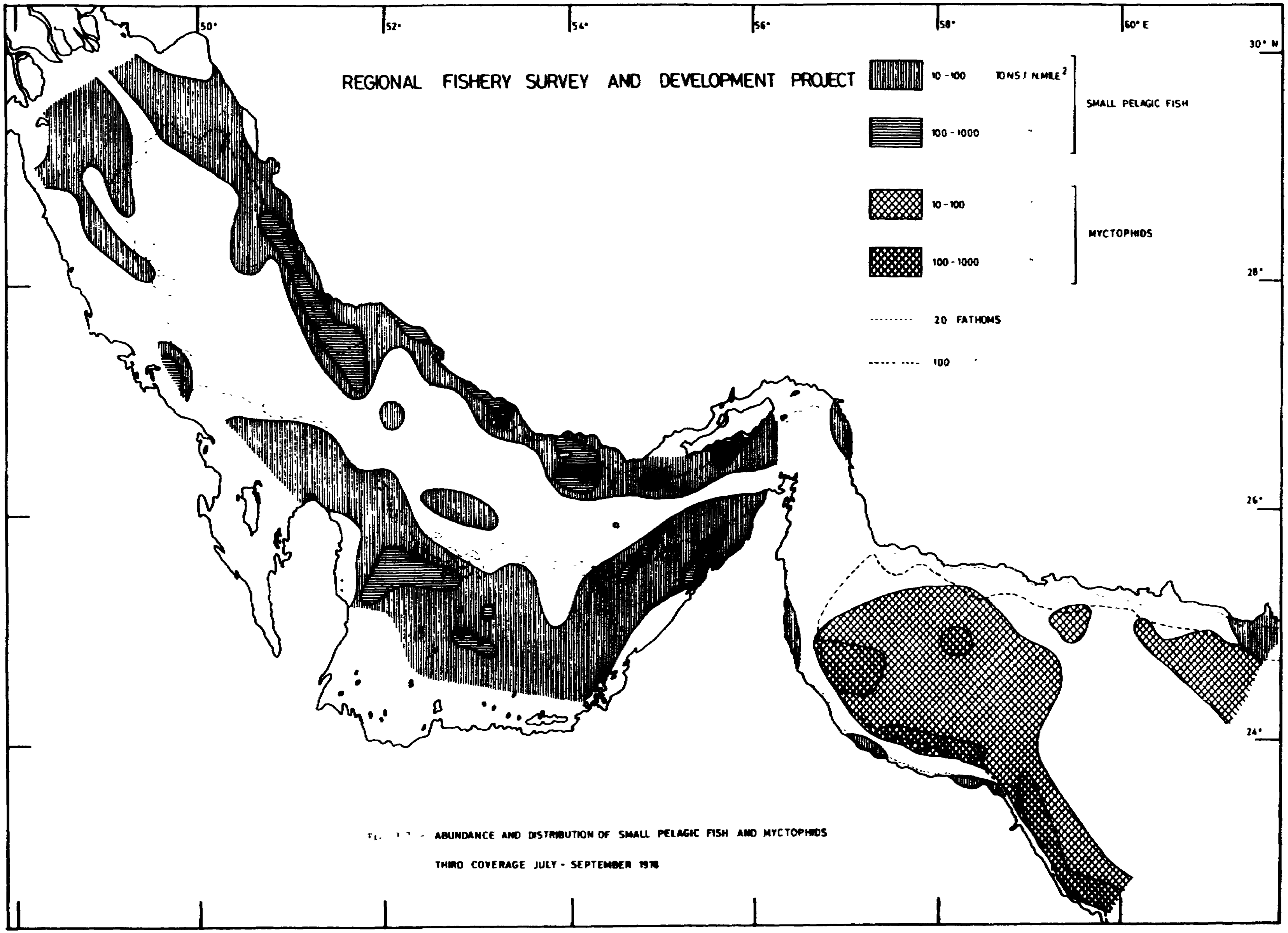


Fig. [illegible] - ABUNDANCE AND DISTRIBUTION OF SMALL PELAGIC FISH AND MYCTOPHIDS

THIRD COVERAGE JULY - SEPTEMBER 1976

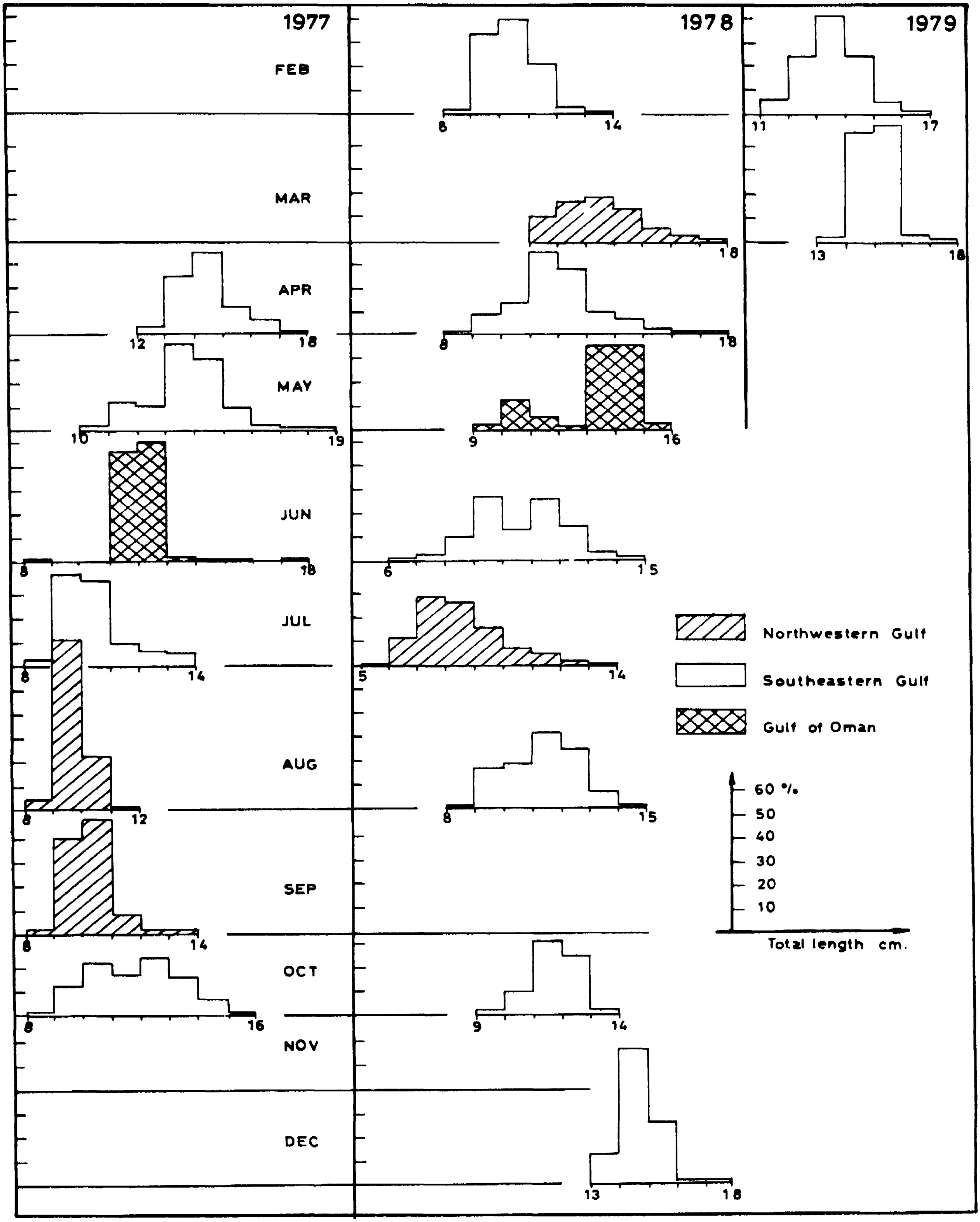


Fig. 3.8 - Length frequencies distributions for Sardinella sindensis

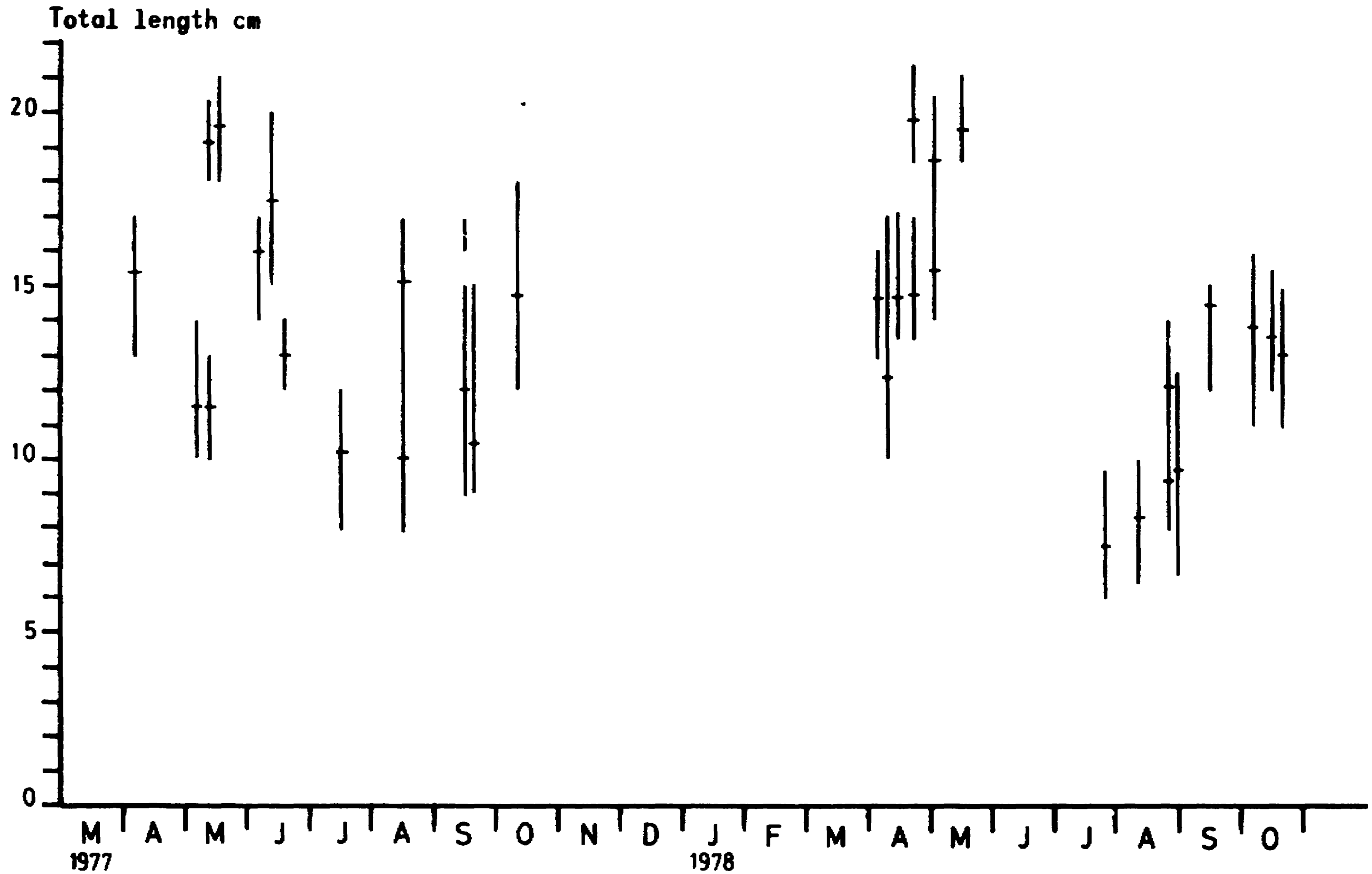


Fig. 3.9 - Size range and modes of the samples of Dussumieria acuta

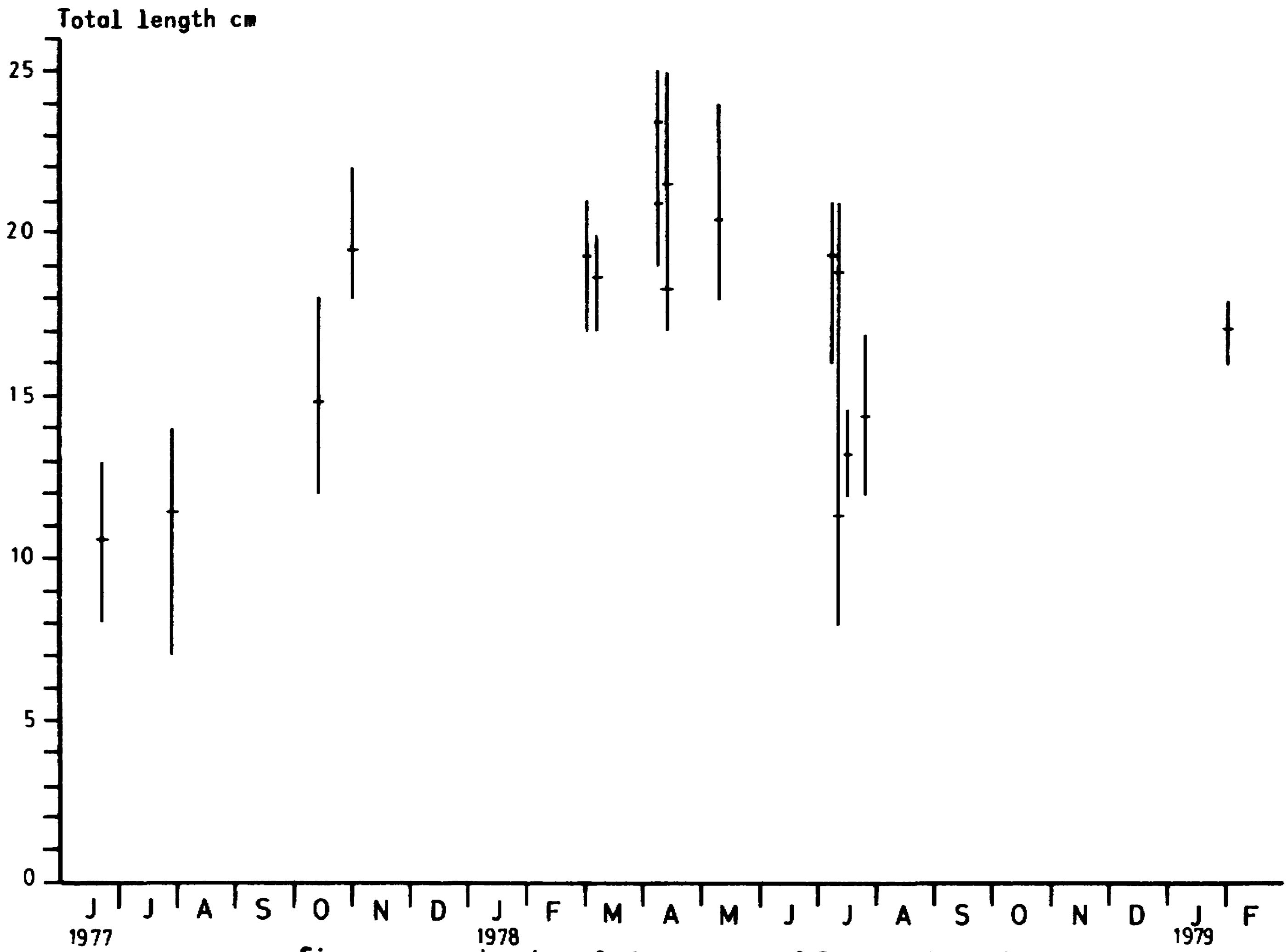


Fig. 3.10 - **Size range and modes of the samples of *Rastrelliger kanagurta***

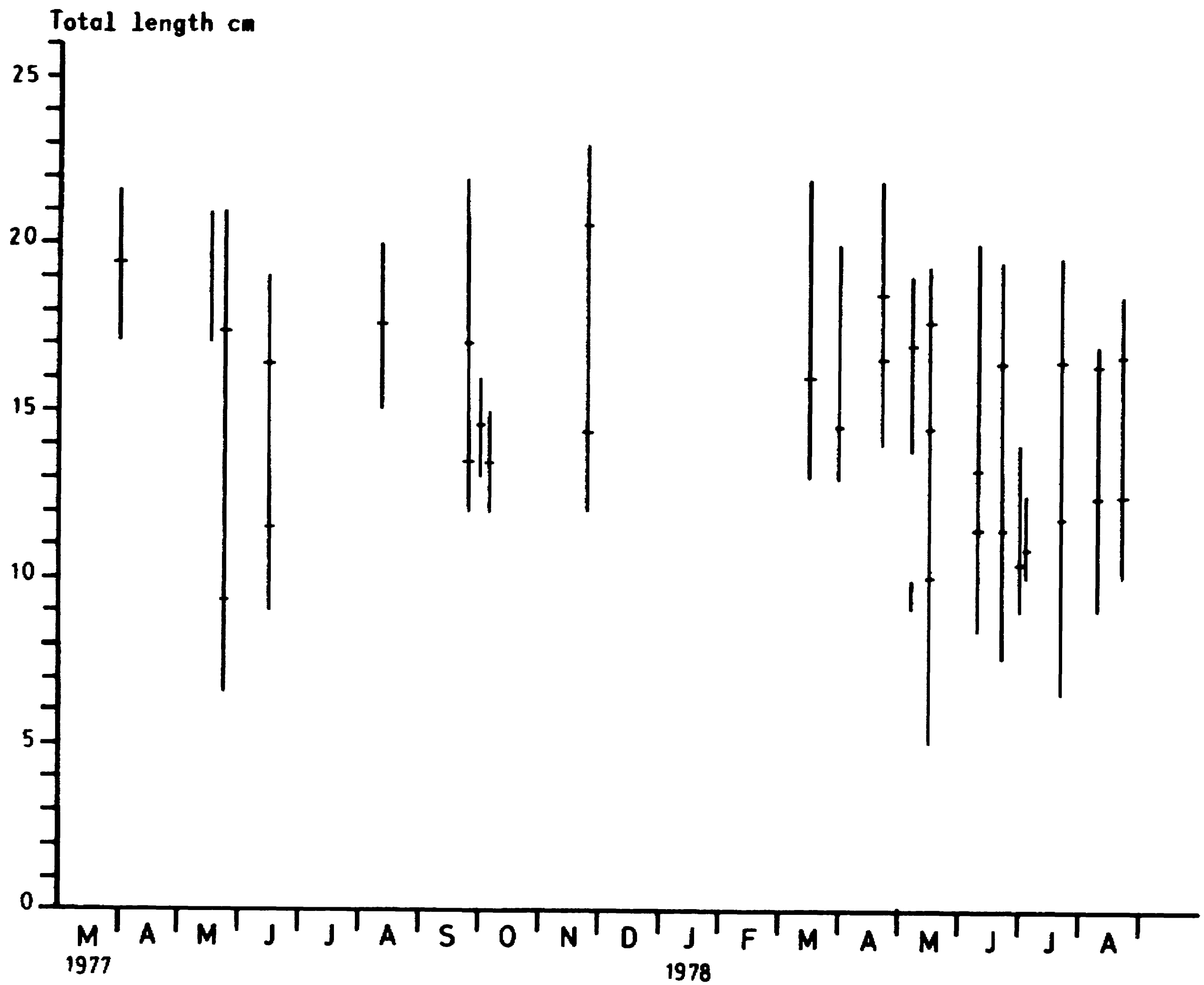
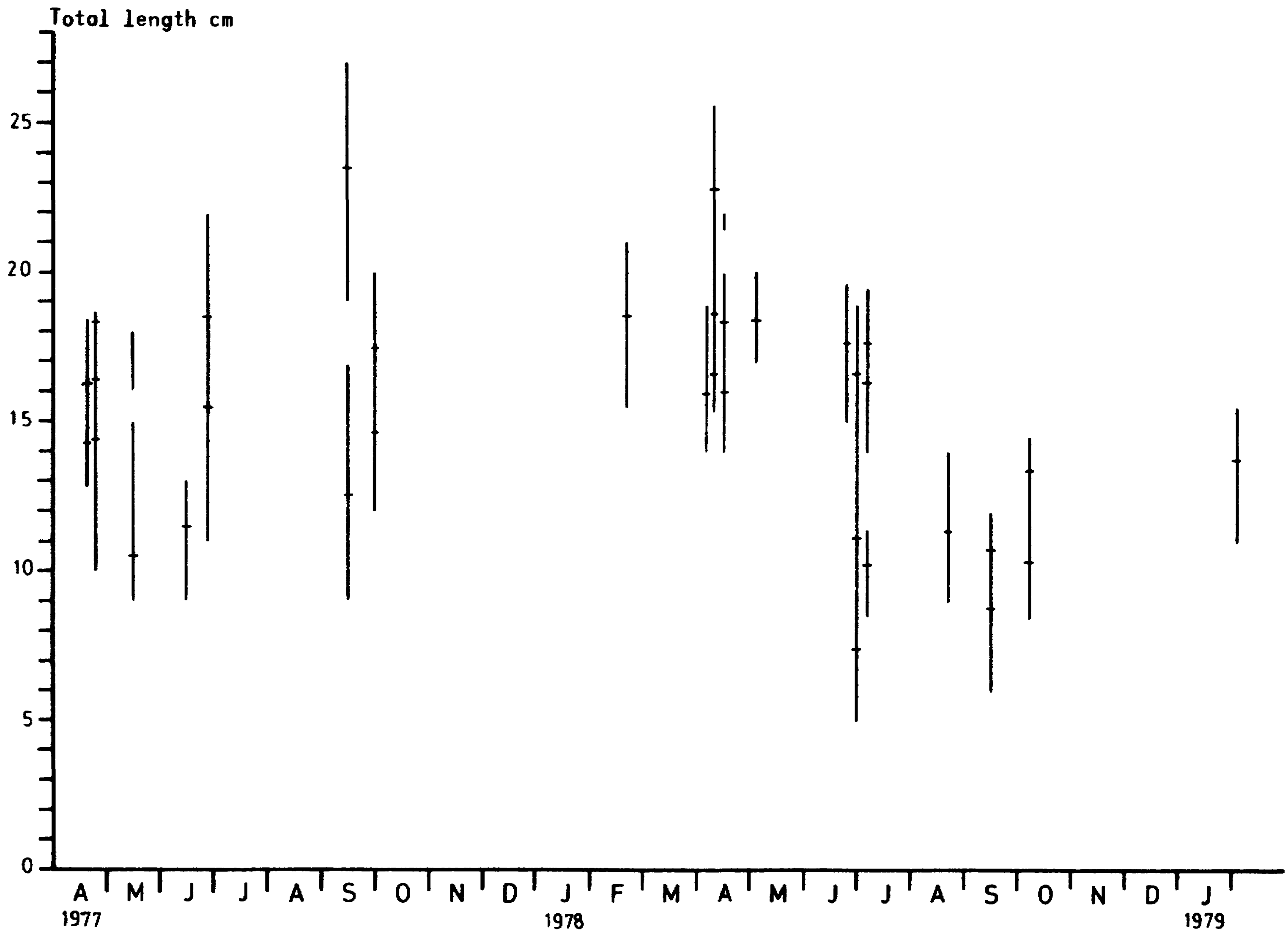


Fig. 3.11 - **Size range and modes of the samples of *Trachurus indicus***



Fi~. 3.12 - Size range and modes of the samples of Decapterus kiliche

Appendix 1 to Part 3

RANGE GATE SYSTEM TO IMPROVE SEA BED ELIMINATION AND CORRECT DETECTION OF MIDWATER SCHOOLS

1. INTRODUCTION

During a survey the integrator receives signals and sums the part of these which come from midwater. To ensure that no signals are included from the sea bed, a sea bed or "white line" pulse is produced by the sounder and fed to the integrator. This is used to stop the integrator interval at the sea bed (when the bottom stop function is used). The conditions under which the sounder produces a white line pulse are determined by the setting of the discriminator switch.

In areas of the Gulf the sea bed changes quite rapidly from soft mud to hard rock and to coral. This means that, to ensure that the sounder correctly produces a white line pulse over these bottom types, a quite high setting of the discriminator is required. When high settings of the discriminator are used, dense schools in midwater will occasionally "block". This means that the signal from the school is strong enough for the sounder to produce an unwanted white line pulse, and this prematurely stops the integrator interval and thus excludes any further signals from that transmission. Thus, under normal conditions a compromise is found between the discriminator setting which will exclude the sea bed successfully and the one allowing schools to be correctly measured. In practice, in the Gulf it has proved, during the first main survey, that the compromise was difficult to make and a substantial number of schools were blocking. This has resulted in a possible source of error and thus significant effort being spent guessing or judging the values of blocked schools.

From the echosounder paper it is easy to determine where the sea bed is. It is simple to see which white line pulses have occurred at the sea bed. The human eye can follow the sea bed, and this continuity is its main identifying feature; if a white line occurs in a school it may not be immediately visible.

The concept of a range gate circuit is that the sea bed is continuous and that schools are not. Thus the depth at which the sea bed white line pulse occurs has an element of continuity, and the depth at which a school can cause a white line pulse is random but restricted to the interval between surface and sea bed.

2. GENERAL DESCRIPTION

The circuit is designed to record where the sea bed occurred and to reject white line pulses which are not sufficiently close to be previous ones to be acceptable as valid sea bed. Thus although schools in midwater may produce unwanted white line pulses, these are rejected and the integrator interval is allowed to continue until the sea bed is detected. It should be stressed that this circuit in no way involves the normal signal path. It is a purely digital circuit designed to remove unwanted white line pulses only.

The basic idea of the circuit can be seen in the block diagram Figure I.1. Counter 1 starts from zero at the transmit pulse and increments until the valid sea bed white line pulse occurs. This loads the value which is on the output of Counter 1 into the store.

At the beginning of the next transmission this value is loaded, from the output of the store, into Counter 2, by the transmit pulse. Then while Counter 1 counts up, Counter 2 counts down at the same rate. Thus Counter 2 reaches zero during this transmission at the point where the sea bed occurred on the previous transmission. The output of Counter 2 is used to produce a "range gate". White line pulses are allowed through to the integrator only during the period the gate is open. This gate is held open only from 1.5 m above until 6 m below the position of the previous sea-bed echo. The same white line pulse which is passed to the integrator updates the store thus ensuring that only correct values are held there.

With the circuit in use, all schools not producing white line will be measured correctly. All schools producing white line, at more than 1.5 m above the sea bed, will be measured correctly. Only schools occurring with white line within 1.5 m of the sea bed will be blocked. These schools will be dealt with as if the circuit had not been present.

The choice of an asymmetrical gate (1.5 m above and 6 m below the sea bed) is based on the differing conditions under which unwanted white line pulses are produced above and below the sea bed. Only second bottom echo pulses are produced below the valid sea-bed echo. Thus, a choice of 6 m margin was made because of the ease with which this could be decoded and the protection against second bottom echoes that it afforded. Should the circuit succeed in locking to the second bottom echo it would require the integrator to treat the first bottom echo as fish, which would be disastrous. The choice of 1.5 m for the upper margin was a compromise.

The circuit was built with a choice of 1.5 m and 3 m (selected by a single switch). In practice, within the Gulf, the depth rarely exceeds 100 m and thus ranges A and B on the EK-S sounder were sufficient for the area. With such high repetition rates (250 and 125 transmission per min) the sea bed does not rise as much as 1.5 m between successive transmissions and so the gate holds the bottom successfully. However, in very bad weather, when the ship is moving up and down, when the echo levels become more unpredictable, the use of a 3-m margin is advisable when the sounder is set to range B. In practice, the 1.5 m margin has been used almost exclusively.

There is a slight degradation to the system. If the sea bed is less than 6 m below the vessel, and if the first sea-bed echo fails to produce a white line pulse and the second echo produces one, the system will lock to the second echo. This is an extremely unlikely set of circumstances. If the sea bed should rise by more then 1.5 m between transmissions (53^{o} slope or vessel move down at 22 km/h) this would cause the sea bed to be accepted as fish. This does not occur except when the weather is too rough for surveying.

Figure I.2 shows an example of rapidly fluctuating sea bed. The white line may be seen on the flat sections of sea bed. Above the sea bed are a series of small schools of anchovy. Although it is not possible to see this on the paper these schools did occasionally white line. The rapid changes in sea bed (20^{o} slope at least) required a high setting of the discriminator (7) this caused slight white line on the schools but these were all measured correctly because of the presence of the range gate system. The start of the integrator interval may be seen approximately 3 m below the transmit mark at the top of the trace. The output from Channel A of the integrator display is shown (Figure I.3). No sharp "jumps" are visible on this indicating, despite the steep slopes, no sea bed was included in the integral. Mile marks may be seen on Figure I.2 and a line showing depth 0-50 m is included. The same log values written down during the survey may also be seen.

3. FULL CIRCUIT DESCRIPTION

To follow this, reference should be made to the circuit diagram Figure I.4. Counters 1 and 2 are formed from two SN 74191's (4bit binary up/down counters). The counters are used with ripple clock output of the first stage (pin 13) connected to the clock input of the following stage (pin 14).

For convenience the store has been formed from the same type of IC. The enable (pin 4) and clock (pin 14) inputs are held high to ensure that the ship does not count.

The transmit pulse from the sounder is used to initialize the circuit. It is matched to the voltage levels for the circuit (0-5 V) by TRI.The negative pulse from TRI is used for the following:

(a) to directly inhibit the clock. This provides the synchronization at the trailing edge of the transmit pulse;

(b) to set Flip-Flop 1 which then enables both Counters 1 and 2 (pin 4);

(c) it is inverted and the OR'ed with the output of Network 2 and used to reset Flip-Flop 2;

(d) it is gated with the Q output of Flip-Flop 2 to ensure that Flip-Flop 2 changes state before the pulse is used to clear Counter 1 (pin 11) and to load the value held in the store into Counter 2 (pin 11).

At the end of the transmit pulse the inhibit is removed from the clock and this provides a 2 kHz clock frequency to the clock inputs (pin 14) of the first stages of both Counters 1 and 2. Counter 1 starts to count up (pin 5 is held low) and at the same rate Counter 2 starts to count down (pin 5 is held high) from the value that has been loaded into it from the store.

Suppose that the value that was in the store is equivalent to the distance between the end of the transmit pulse and the sea bed in the previous transmission.

Counter 1 and Counter 2 continue to count, Counter 1 increasing its value and Counter 2 decreasing its value. When Counter 2 reaches the value 14 (SWL in position shown) a pulse is decoded by network 1 and fed to Flip-Flop 2 which it sets. The value '4' corresponds to a distance of 1.5 m above the position of the previous sea-bed echo. Flip-Flop 2 is used to gate the white line pulses produced by the sounders. These are fed through TR2, inverted, and then gated with theoutput of Flip-Flop 2. So, until 1.5 m above the previous sea-bed echo no white line pulses pass through to the rest of the circuit. After this point in time the state of Flip-Flop 2 changes and the inhibit is taken off the gate.

The counters continue to count. Counter 1 and Counter 2 to increase and decrease their values respectively. Under normal circumstances the sounder will produce a white line pulse at the sea bed. When this is produced this can pass through the gate opened by Flip-Flop 2. This pulse is then increased in amplitude (to 12 V) and fed out through SW2 to the QM Integrator. This pulse takes the place of the normal bottom pulse provided by the sounder and usually fed directly to the integrator. SW2 is provided to switch this pulse with the normal bottom pulse to allow the circuit to be taken out if so required.

Once the white line pulse has passed through the range gate, opened by Flip-Flop 2, it is gated with the clock. This then resets Flip-Flop 1. Flip-Flop 1 must only change state when the clock input to the counters is high. This has been assured by gating as just mentioned. Flip-Flop 1 is reset and this takes the enable from the counters thus holding the value in Counter 1 steady.

The same pulse used to reset Flip-Flop 1 is fed to the load input (pin 11) of the store. Thus the value held in Counter 1 is transferred to the store. This value is equivalent to the distance between the end of the transmit pulse and the white line pulse produced at the sea bed. As the counters have ceased to change value, any further white line pulses will not affect the value in the store. Thus for the following transmission the correct value will be held in the store.

If it should happen that no white line pulse is received from the sounder then Network 2 will decode a pulse at a point in time equivalent to 6 m below the previous sea-bed echo. This is used to reset Flip-Flop 2 to avoid the possibility of the system locking to the second bottom echo. When no white line pulse is produced no stop signal is sent to the integrator. This is exactly what happens normally when no bottom pulse occurs. Because midwater white line pulses have been excluded the discriminator may be set a little higher then previously considered optimum, thus reducing the chance of this occurring.

In order that the system may initially lock to the sea-bed and then continue automatically to follow it SW3 is provided. When held down for the duration of one transmission this push bottom SW3 will hold Flip-Flop 2 set. This will lock the circuit to the first white line pulse from the transmission under consideration. Thus if no schools are causing white line in midwaters, the circuit will store the correct value. This will continue to be updated every transmission irrespective of the presence of white line pulse from midwater.

4. SOME FURTHER POINTS

4.1 The Clock

This is an RC network with Schmitt trigger inverter and provides approximately 2 kHz. This is not a particularly stable frequency source but its short-term stability is the most important requirement. About 0.1 percent variation per second would be tolerable and a long-term stability of 1 percent is required, this oscillator will give both these easily.

4.2 Depth Capability

The circuit shown can cope with sea bed up to 90 m in depth. This is adequate for the Gulf. There are two possible methods of extending this:

(a) to decrease the clock frequency - this changes every feature proportionally. Half the frequency (1 kHz) will give minimum 3 m margin (optional 6 m) with 12 m exclusion of second bottom echo. If the clock frequency was switched with sounder range this would give quite a sensible result. But the circuit would have to be relocked when the range was changed. At the moment it works independently of sounder repetition rate.

(b) to add a further stage to the counters, store and decoder networks - a third stage would extend the range to beyond 600 m. Greater depths and therefore slower repetition rates might require different margins (1.5 m or 3 m might be too small) but these could be easily decoded.

4.3 Power Supply

The 24 V rail from sounder (normally fed to High Power Transmitter) provides power for this circuit. This is adequate but very wasteful as only 5 V is required with any substantial current. A separate supply would be more suitable.

5. CONCLUSIONS

The circuit has been used during the second and third seasonal coverage and has performed well during each.

The use of this counter and store system is not new, it has been used before in the Aberdeen integrator. But the precise circuit was developed for this area. It would be possible with only very minor alterations to use such a circuit in other areas.

The use of such a device greatly reduces the necessity to judge or guess the value of schools, which would otherwise not have been measured correctly. This not only improves the accuracy of the equipment, it also reduces the time involved in checking through the echosounder rolls after they have come off the sounder. The slight degradation to the system, due to the presence of the circuit, is greatly outweighed by the benefits resulting from its inclusion. Because the danger of mis-measurement of schools is reduced, the discriminator may be set a little higher (1 or at the most 2 steps) to almost totally remove the possibility of erroneously including sea-bed echoes, along with fish echoes.

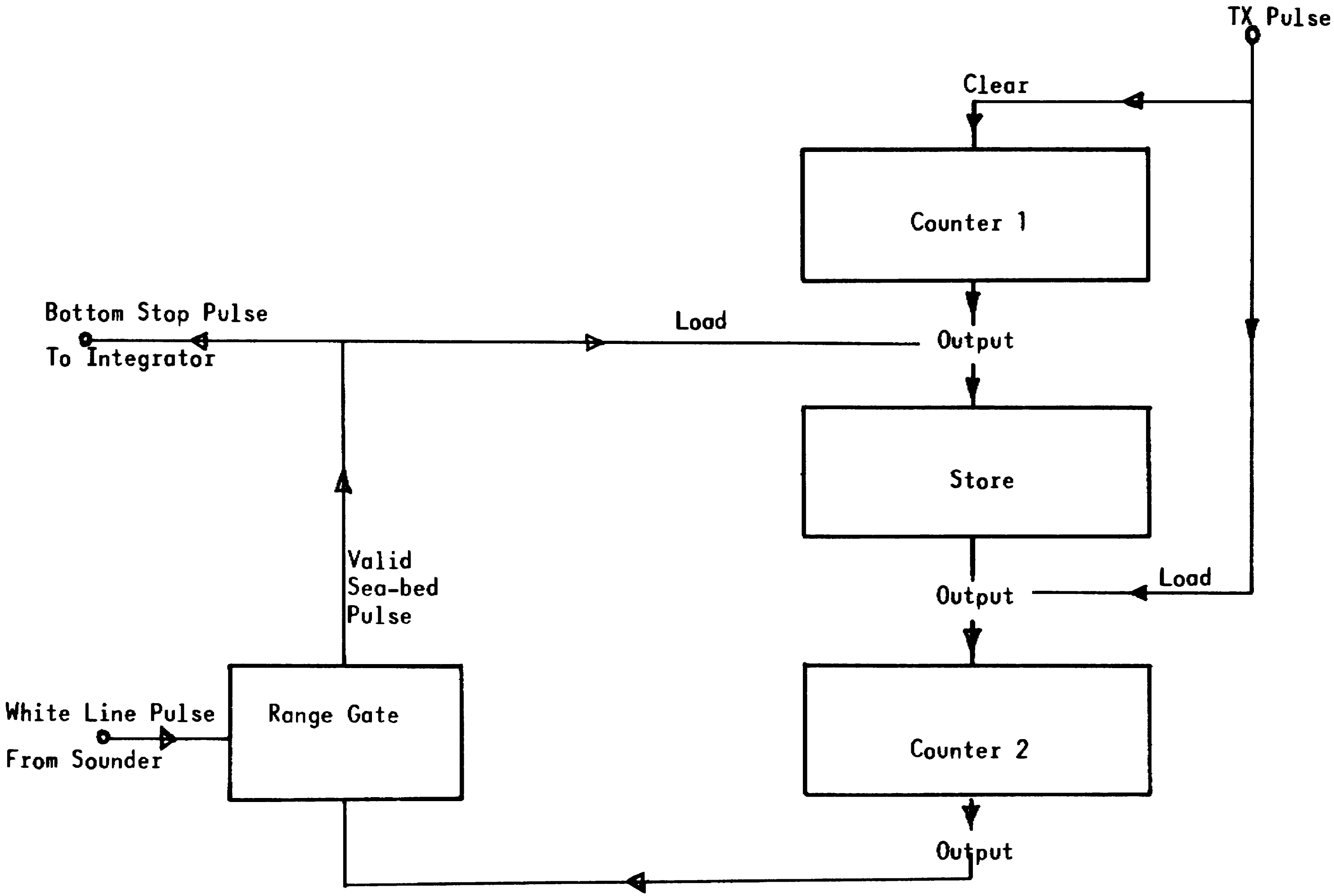


Fig. I.1 - Block diagram of range rage system

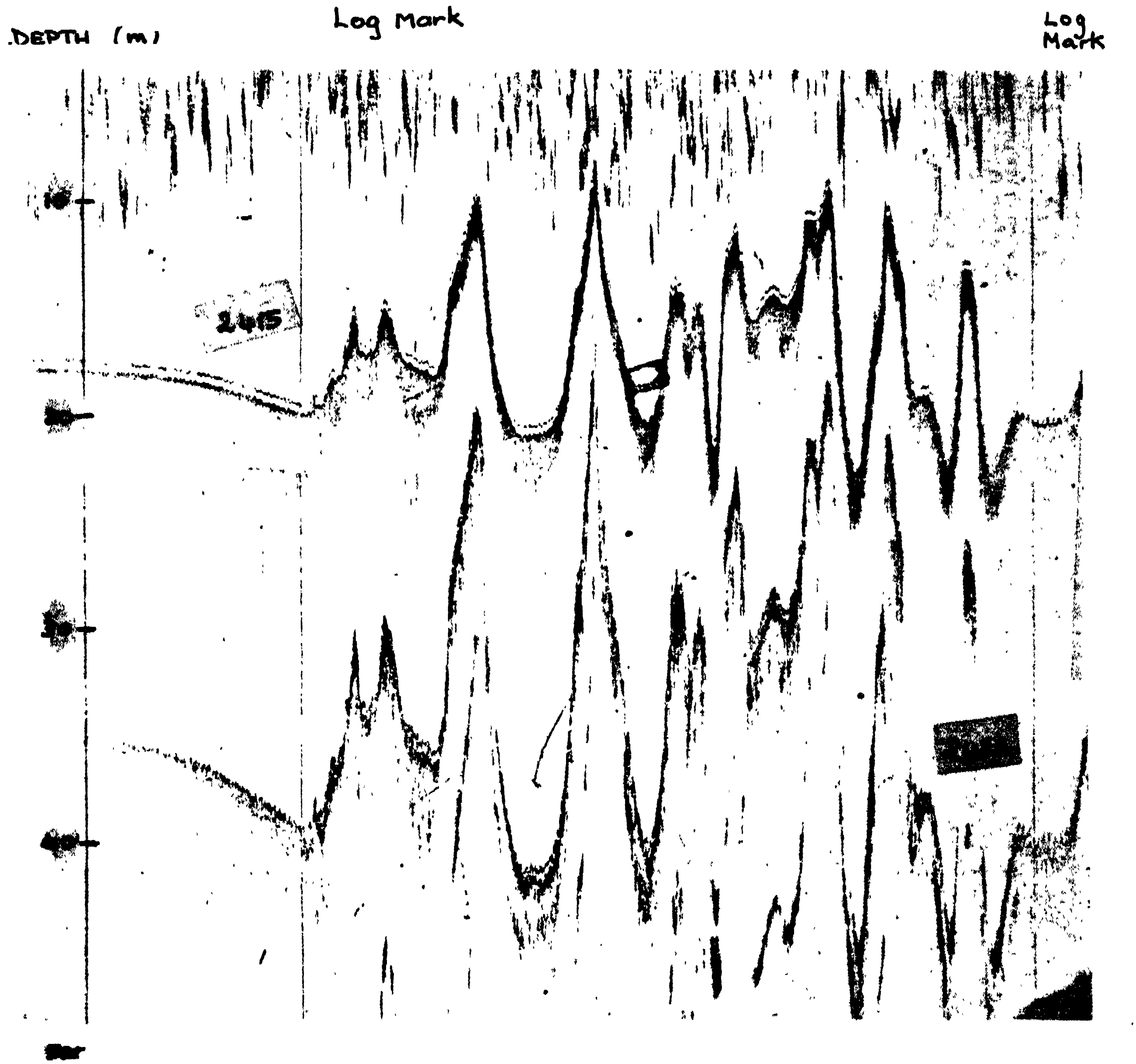


Fig. I.2 - Echo sounder paper

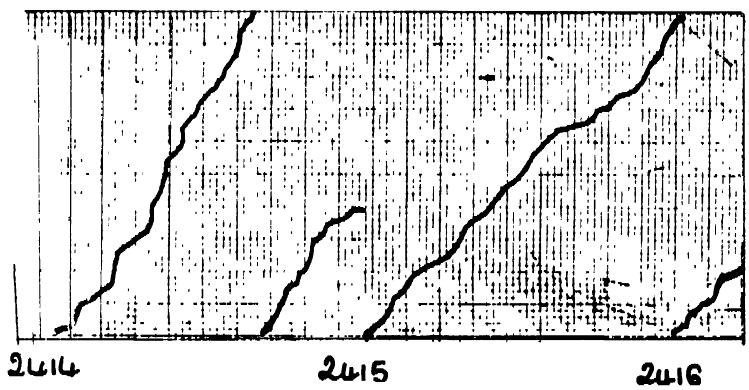


Fig. I.3 - Integrator paper

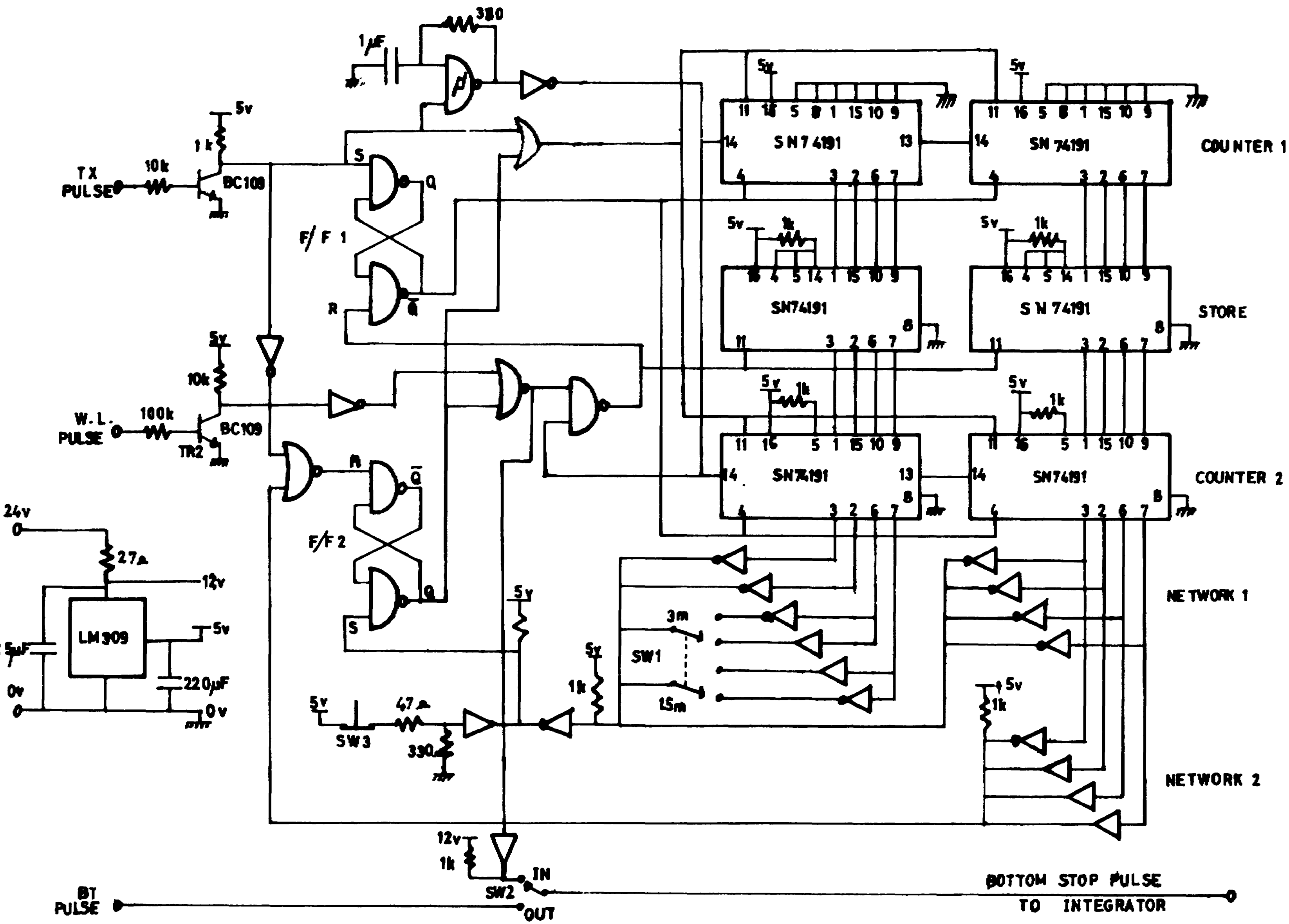


Fig. I.4 - Circuit diagram

Appendix 2 to Part 3

LIVE FISH CALIBRATION

This work was carried out during February in the inlet Khor Ash Shamm, situated inside the Gulf close to the Strait of Hormuz. Three experiments, two on *Sardinella sindensis* and one on a mixture of *Decapterus kiliche* and *Selar crumenophthalmus*, were performed.

1. MATERIALS

1.1 Fish

All the fish used in these experiments were caught inside or at the mouth of the inlet Khor Ash Shamm. The fish were concentrated close to the vessel using a surface light. When sufficient fish had been attracted to the light, they were encircled using a small purse seine, which was built specially for this work and shot from a skiff. The purse seine was closed and partially taken onboard, the outer part was held clear of the vessel to allow the fish to swim. The fish were then caught using a bucket and transferred to the vessel.

Onboard were three tanks containing sea water. Fresh sea water was pumped continuously from the side of the vessel into the tanks and then allowed to flow back over the side. The caught fish were transferred by bucket and placed in the tanks. Careful watch was kept on the fish, those that died were removed from the tanks immediately. The tanks were also cleaned regularly. This was essential during the first few hours to reduce poisoning of the water. The initial mortality of *D. kiliche* and *S. crumenophthalmus* was much lower than that of *Sardinella* and did not change during the time they were kept in the tanks. After a period of acclimatization the fish were transferred to the experimental rig. For *S. sindensis* this occurred 48 h after they were first caught. *D. kiliche* and *S. crumenophthalmus* were transferred 6 h after being caught. This shorter period of time for small Carangidae was because their initial mortality was very much lower, and because only a limited amount of time was available to complete the experiment.

1.2 Experimental Rig (Figure II.1)

In order to carry out this work fish must be positioned below a transducer. It is inconvenient to use the hull-mounted transducer, which is normally used for surveys. Instead, a spare transducer was used. This was connected to the ships echosounder as a direct replacement for the hull-mounted transducer. The spare transducer was then placed on the top of the experimental rig. Below this was hung a cylindrical net cage supported by two metal rings, diameter 2.3 m, height 2.5 m and mesh size 20 m. The cage was hung on three ropes and held taut by a weight suspended below it. The distance between the transducer and the top of the cage was 3.75 m. The transducer was supported on a triangular frame with sides of 1.3 m. The supports from the frame to the upper ring were slightly inclined to the vertical, this held the cage in line with the frame, and ensured that the cage did not slide sideways if any current was present. The triangular frame was suspended on three wires with a bottlestop adjustment on each wire. These were adjusted to ensure that the transducer was pointing straight down. The complete rig was suspended on a single wire. The narrow beam mode of the transducer was used. The transducer is rectangular and the beam is therefore elliptical. Figure II.1 shows the pattern corresponding to the long axis of the ellipse. The dotted lines on the drawing show the position of the -9dB points of this beam, between which 99 percent of the energy passes. The rig was designed to ensure that 99 percent of the energy passes through the cage.

2. MEASUREMENT METHOD

2.1 Rig Alignment

To make correct measurements the acoustic axis should lie through the centre of the rig. A target (ping pong ball) was suspended 5 m below the transducer (position of the centre of the cage). The direction of the beam axis was adjusted to the vertical. To do this, bottlestops - connected on the support wires - were adjusted to obtain a maximum value for the target.

2.2 Equipment Performances

To check the system sensitivity, first, the performance of the hull transducer was checked using the hydrophone. Then, a standard target (ping pong ball) was suspended below the hull transducer and the target strength of this was determined. The same target was suspended below the transducer used on the experimental rig and the values for the two measurements compared. The hydrophone measurement on the hull system provided the absolute figures of Source Level and Voltage Response. The check with a standard target confirmed it, by comparing a known target strength value (of -42dB) for the standard target with the measured value using the Source Level and Voltage Response values obtained by the Hydrophone measurements. The comparison between systems using the same standard target provided a correction factor from one transducer to the other.

To measure the fish once they had been placed in cage the rig was lowered to the operating depth of 8 m. The echosounder system was then run in the same way as on a survey. The two integrator channels were each set to 1 m depth interval and adjusted to lie within the cage, and not overlapping each other. The lower channel of the integrator was set so that it was clear of lower ring echo, the upper channel was set directly above the lower one. The positions of the two channels may be seen on Figure II.1. The speed compensation on the Integrator was set to give the same voltage (5.4 V) as that provided by the ship's log, when the vessel was steaming at normal survey speed (approximately 8 knots). A nautical mile reset was provided by a circuit (see Appendix 3) which counted the number of transmissions and reset the integrator after the correct time (7 min 34 sec). The correct setting of the speed compensation and the nautical mile reset was checked by providing the integrator with the same signal normally used to check its gain during the survey.

2.3 Background Noise and Reverberation

In order to determine the reverberation contribution of the cage, a series of measurements were made on the empty cage. Tha gain on the integrator was increased in order to get sensible measurements, but results are given below at the normal operating levels. In the measurements made between experiments 1 and 2, the dead fish from experiment 1 were left in the cage to check the contribution of those dead fish which had been lying at the bottom of it. Each value of reverberation presented below was the result of measurements averaged over at least one hour.

2.4 Experiments with Live Fish

A similar method was used for each of the three experiments, with live fish:

Experiment 1 on Sardinella sindensis (Length frequency in Figure II.2)
Experiment 2 on Sardinella sindensis (Length frequency in Figure II.3)
Experiment 3 on a mixture of 55 percent Selar crumenophthalmus (Length frequency in Figure II.4)
45 percent Decapterus kiliche (Length frequency in Figure II.5)

The fish were introduced to the cage using a bucket to catch them in the tanks and carry them across the deck. They were then poured through a large funnel into the cage (see photographs p. 82). To ensure that no abrasion was caused while the cage was lowered, this was done slowly and the behaviour of the fish continuously observed. During all experiments the behaviour of the fish and the mortality were checked periodically by divers. Each experiment lasted for two days. During the first day the fish were left to acclimatize to the cage, and then during the second day the actual measurements were made. During the whole of each 2-day period, the integrator was producing a value every 7 1/2 min.

In order to determine the weight of live fish in the cage, the number of dead fish was observed regularly by divers. It was assumed that the fish died at a linear rate between observations. At the end of each experiment both the live and dead fish were weighed, and the weight and the number of live fish calculated for all parts of the experiment.

3. RESULTS

3.1 Equipment Performance

3.1.1 Normal operating values for the system were measured by hydrophone and test equipment onboard LEMURU.

The sounding equipment is a Simrad EK-S 38 sounder with a 69 M (15 x 30/10 cm) transducer and Simrad echo integrator QM MK II, operated with the settings given below:

EK-S 38	Output	1/1
	Receiver gain	OdB
	TVG	20 log R/OdB
	Pulse Length	0.6 msec
	Receiver bandwidth	3kHz
	Recorder gain	5
	Mode	WL (white line)
	Discriminator	6
	Beam	Narrow

Echo integrator: Simrad QM MK II and Hewlett Packard recorder 7702B used with the following settings:

Gain	10dB
Scale expander	X 10
Threshold	2
Speed compensation	Automatic
Bottom Stop	ON

The results of the performance check give the following values for the Survey Transducer:

SL (Source level)	= +116.1 dB rel 1μ bar
VR (Voltage response)	= + 2.0 dB rel 1μ bar/V_{rms}
10 log ψ (Equivalent beam angle)	= - 18.0 dB rel 1 steradian
10 log C τ/2 (Pulse length)	= 3.5 dB rel 1 m
I_o (Integrator gain)	= + 26.2 dB rel 1 mm/V_{rms} m/n.mi
TVG curve	shown in Fig. II.6

For this measured TVG curve a best fit theoretical TVG has been determined. The equation for the receiver gain then becomes:

Receiver gain = $- 62.7 + 20 \log R + 2\alpha R$ dB rel 1 V/μ bar for operation between 5 and 150 m

α is a calculated value using average salinity and temperature readings from hydrographic stations

R is range in metres

This equation describes the performance of the receiver. This may be submitted in any other equation or can be used to calculate the receiver gain at any range, as shown below:

For α = .0064dB per m for S = 38.5°/oo, T = 26°C

VR_{1m} Receiver gain at 1 m = -62.7dB rel 1V_{rms}/μ bar

VR_{100m} Receiver gain at 100 m = -21.4dB rel 1V_{rms}/μ bar

VR_{500m} Receiver gain at 500 m = - 2.3dB rel 1V_{rms}/μ bar

I_o, the integrator gain, is the gain between the input of the integrator and the output display. To measure I_o, the integrator settings are as above with channel settings of 10 m depth slice. Sounder settings are as above with Output Power set to External.

A CW signal is applied at the Recorder Playback input to the sounder, and is measured at the calibrated output.

Signal at calibrated output	= -10dB rel 1V_{rms}
Channel output	= 420mm/n.mi for 10 m
Channel output	= 42mm/n.mi for 1 m
Channel output	= 10 log 42dB rel 1 mm/n.mi
Channel output	= +16.2dB rel 1 mm/n.mi
Integrator gain	= +16.2 + 10dB rel 1mm/V_{rms}/n.mi
I_o	= 26.2dB

(A note on the Determination of the Receiver Gain by J. Simmonds follows as Annex)

3.1.2 A comparison between the two systems, using the ping pong ball as a standard target, was undertaken. For a ball under the transducer the intensity reflected from the ball is 20 log V_{rms}.

Ball under calibration rig = -13.2dB (ball at 4.9 m, O/p power set to 1/10)

Ball under survey transducer = -8.4dB (ball at 5 m, O/p power set to 1/1)

Difference between systems = +5.0dB

The setting for these measurements are the same as those shown above (Section 3.1.1) except for the EKS 38 output power, which was set as indicated above.

3.1.3 In both systems measurements were made at 5 m, with a TVG running. The receiver gain (at this range) was slightly greater than the value predicted by the above equation (3.1.1).

This is because there is +0.4db error in the TVG at this point (Figure II.6).

3.1.4 Background noise and reverberation level (mm/n.mi). Before and between experiments, measurements of the reverberation level were made.

	No. cage	Empty cage			
		Before experiments	Between experiments 1 and 2 1/	Between experiments 2 and 3	After experiments
Upper channel	0.07	3.1	5.3	4.3	1.4
Lower channel	0.08	0.15	0.9	0.18	0.19

1/ For these values the dead fish were present on the base of the cage

In order to compensate for the background reverberation due to the cage the following values are subtracted from the integrals.

Upper channel 4 mm
Lower channel 0 mm

3.1.5 Rig Parameters

Cage dimensions: Height = 2.5 m
Diameter = 2.3 m
Volume = 10.4 m^3
Distance from transducer to centre of Cage = 5 m

The information provided in the above paragraphs defines all the systems parameters that are required.

All following calculations are made using the measurements and values relating to the equipment during the surveys This is because the individual measurements of SL, VR, etc., have been carried out on the survey transducer, whereas only a comparative measurement has been carried out on the calibration transducer.

3.2 Live Fish Calibration Experiments

3.2.1 The fish were weighed, counted and measured at the end of each experiment. The weight of fish in the cage was estimated by assuming a linear mortality during the measurement period.

Overall mortality for Exp. 1 and 2 and Sardinella sindensis was similar in both experiments, less than 10 percent died over the 2 days. Overall mortality for Exp. 3, the mixture of Decapterus kiliche and Selar crumenophthalmus, was slightly higher but still less than 16 percent over two days.

Effective weight of the fish Exp. 1 = 10.36 kg
Exp. 2 = 11.12 kg
Exp. 3 = 7.82 kg

3.2.2 Density of Fish

Using the volume of cage from above (3.1.5)
Density of fish
Exp. 1 = 1.00 kg/m^3
Exp. 2 = 1.07 kg/m^3
Exp. 3 = 0.75 kg/m^3

3.2.3 Integrator Readings

The average integrator readings mm/n.mi minus the reverberation figures discussed above (3.1.4) are shown in Figures II.7, II.8 and II.11.

During Experiment 1 and Experiment 2 the Sardinella moved out of the lower interval during dark hours. This was determined by watching the echo signal on the oscilloscope. All the variable echo, normally associated with the presence of fish, was in the lower part of the lower interval or below it. Any measurements during this period were inaccurate because the fish were not within the measurement interval.

Therefore, to determine the average value for these two experiments, the last 12 hours of day-light were used.

For Experiment 3 the last full 24-h period was used because the fish were distributed all over the cage at all times of day and night. To give an idea of the vertical distribution of the fish within cage the integrator readings from the two channels are plotted separately in Figures II.9, II.10 and II.12.

The average integrator readings are:

Exp. 1 = 214 mm/n.mi for 1 m interval - 12-h average (daylight)
Exp. 2 = 248 mm/n.mi for 1 m interval - 12-h average (daylight)
Exp. 3 = 221 mm/n.mi for 1 m interval - 24-h average

3.2.4 Standardized readings for 1 kg of fish per cubic metre using the values of density worked out above (3.3.2).

Exp. 1 = 214 $mm/n.mi/kg/m^3$
Exp. 2 = 232 $mm/n.mi/kg/m^3$
Exp. 3 = 295 $mm/n.mi/kg/m^3$

3.2.5 These experiments were conducted with the cage at 5 m from the transducer. As discussed above this point on the TVG curve is 0.4dB too sensitive (3.1.3) (Figure II.6).

The system was also operating at reduced power with a different transducer from one used for the survey. The difference of sensitivity was 5.0dB (3.1.2).

combining these two factors there is a reduced sensitivity of:

5.0 - 0.4 = 4.6dB

To compensate for this the above figures (3.2.4) are corrected, by multiplying with the antilog of 4.6.

Exp. 1 = 617 $mm/n.mi/kg/m^3$
Exp. 2 = 669 $mm/n.mi/kg/m^3$
Exp. 3 = 851 $mm/n.mi/kg/m^3$

Thus these results are referred to normal survey conditions. These "normal survey conditions" refer to the performance values quoted at the beginning of the results (Section 3.1).

3.2.6 Experiments 1 and 2 give the integrator output for Sardinella.

The average value for Sardinella sindensis becomes 643 $mm/n.mi/kg/m^3$.

The fish in Experiment 3 consisted of a mixture of 45 percent Decapterus kiliche and 55 percent Selar crumenophthalmus. The value = 851 $mm/n.mi/kg/m^3$ relates to this mixture.

3.2.7 Determination of absolute Area Back-scattering Strength (S_A)

$$S_A = F - SL - VR_m - 10 \log \psi - 10 \log C\,\tau/2 - I_o$$

where (from 3.1)

SL source level	= +116.1dB rel 1μ bar
VR_m voltage response ref. 1 m	= - 62.7dB rel 1 V_{rms}/μ bar
10 log ψ equivalent beam angle	= - 18 dB rel 1 steradian
10 log C τ/2 pulse length	= - 3.5dB rel 1m
I_o integrator gain	= + 26.2dB rel 1mm/V_{rms} n.mi
F Sardinella sindensis 10 log 643	= + 28.1dB rel 1mm/n.mi
F Decapterus and Selar 10 log 851	= + 29.3dB rel 1mm/n.mi

Substituting these values in the above equation:

S_A = -30 dB per kg/m^2 for Sardinella sindensis
S_A = -28.8 dB per kg/m^2 for mixture of 45 percent Decapterus kiliche and 55 percent Selar crumenophthalmus
S_A the back-scattering strength is related to the Target Strength TS
S_A x Area/weight = TS/weight

For Sardinella sindensis

S_A = -30 dB per kg/m^2, thus the target strength TS = 30 dB/kg

For the mixture of small carangids

S_A = 28.8 per kg/m^2, the TS = -28.8 dB/kg

3.2.8 Integrator Constants

As well as providing absolute back-scattering strength figures this information also provides conversion factors for the survey data. The transformation of the figures from Section 3.2.6 into $t/n.mi^2$ gives the following value for the two species groups:

Sardinella sindensis	5.3 $t/n.mi^2$/mm ref. to 1 n.mi
Mixture of Decapterus and Selar	4.0 $t/n.mi^2$/mm ref. to 1 n.mi

4. DISCUSSION AND CONCLUSION

These results do leave some questions unanswered. They do not indicate possible variations between day and night for Sardinella sindensis. The possible differences between Decapterus kiliche and Selar crumenophthalmus are not known. The other problem which has not been investigated is the possible non-uniformity of distribution within the cage. Observations by divers indicated that the fish were behaving normally, as a small school. Other schools of similar size and density were observed in the same area. Values between -29 and -30dB are usual for fish of this size. Discussions by experts at the ACMRR meeting in Aberdeen in December 1977 indicated that these results are in agreement with the general observations being made by scientists around the world (ACMRR/FAO, 1978).

This gives results for Sardinella sindensis, Decapterus kiliche and Selar crumenophthalmus. In order to find constants for other species involved, some assumptions have to be made.

It is suggested that for Trachurus indicus and for Rastrelliger kanagurta the values for the mixture of Decapterus kiliche and Selar crumenophthalmus may be used.

The other main species group is Stolephorus sp. In order to determine the integrator constant for this stock the following relationship was used:

$$C_{St} = C_{Sa} \sqrt{\frac{L_{St}}{L_{Sa}}}$$

Where C_{Sa} = constant for Sardinella sindensis = 5.3

L_{St} = mean length for Stolephorus sp. = 6.0 cm

L_{Sa} = mean length for Sardinella sindensis =10.6 cm

and C_{St} = constant for Stolephorus sp.

This relationship is suggested by S.T. Forbes in "Absolute Estimates of Fish Target Levels from Live Fish Experiments" (paper contributed to ACMRR Mtg. in Aberdeen, December 1977).
If we use the same method for the mesopelagic stocks found in the Gulf of Oman we have the following constants for the main species encountered during the survey.

Summary Table

Area Back Scattering Strength and Resultant Integrator Conversion Constants Used for Survey

Measured Values

Species	Area Back-Scattering Strength (dB/kg/m^2)	Integrator Conversion Constant (t/mm^2/mm ref. 1 n.mi)
Sardinella sindensis	-30	5.3
Decapterus kiliche (45%) + Selar crumenophthalmus (55%)	-28.8	4.0

Assumed Values

Species	Area Back-Scattering Strength (dB/kg/m^2)	Integrator Conversion Constant (t/n.mi^2 mm ref.1 mm)
Trachurus indicus	-28.8	4.0
Rastrelliger kanagurta	-28.8	4.0
Myctophidae (5.2 cm, average length)	-28.4	3.7
Stolephorus (6 cm, average length)	-28.8	4.0

Annex to Appendix 2

NOTE ON THE DETERMINATION OF THE RECEIVER GAIN

by

J. Simmonds

For the signal to be in the correct form for integration range compensation is required: $20 \log R + 2 \alpha R$. If it is not in this form fish densities at different ranges will be incorrectly averaged or compared.

So the receiver gain must take the form:

Receiver gain = $A + 20 \log R + 2 \alpha R$

where A is a fixed gain

R is a range in metres

α is attenuation coefficient (for Gulf = .0064 dB/m)

If $R = 1, 20 \log R = 0$

$2 \alpha R = .0128 \approx 0.\text{dB}$

Therefore the receiver gain at 1 m on the TVG sweep = $A + 0 + 0 = A$

However this point does not exist in a Simrad sounder and cannot be measured directly. Also the TVG characteristic which is provided is not perfect. There are two reasons for this:

(1) it is not possible to set it up correctly to a desired curve;

(2) it is set for $\alpha = 0.01$ dB/m which is reasonable for the Northeast Atlantic but not for all other areas of the world (for example the attenuation coefficient is 0.0064 dB/m in the Gulf).

So, to determine A are required:

(1) a gain measurement of the receiver at a known point on the TVG characteristic; and

(2) a determination of errors between actual and required TVG characteristics.

The required gain characteristic may be calculated as $20 \log R + 2 \alpha R$ from 1 m range. With $R = 1, 20 \log R = 0$ dB

$2 \alpha R = .0128 \text{ dB} \approx 0 \text{ dB}$

The calculated characteristic is shown on Figure II.6 as the solid line. The scale on the left refers to this curve.

The next step is to measure the relative gain changes along the TVG characteristic of the sounder.

This shows gain changes from 4 m to about 500 m. After 500 m the gain changes only by small amounts and by 700 m it is completely constant. The relative changes do not correspond exactly (between 4 and 500 m) to the relative changes of the required characteristic.

For example in Figure II.6 the gain change on the measured curve between 5 m and 100 m is 0.4 dB less than in the required curve. Also the gain change between 100 m and 500 m on the measured curve is about 4 dB more than on the required curve.

By calculating the differences between relative gain changes on the required curve and the relative gain changes on the measured curve a set of values of error can be determined. It is possible to minimize this error over the whole or part of the range 4 to 500 m. In the case of the Gulf survey the author chose to do this over 5 to 150 m which were the ranges of interest. If however a fit was required only between 300 and 500 the dotted line on Figure II.6 would have to be drawn about 3.5 dB lower.

The other requirement is a gain measurement on a known point on the receiver TVG characteristic. This has been done on the linear region beyond 700 m on the TVG. This is a hydrophone measurement and is called by Simrad the "Voltage Response" or VR. This is quoted in the report as +2 dB relative to 1 volt/μ bar.

On Figure II.6 the horizontal part of the dotted line on the right of the diagram is labelled +64.7 dB rel to 0 dB at 1 m. This could be written as 1 m on the required curve is -64.7 dB relative to the final gain of the receiver. But we know that the final gain of the receiver is +2 dB relative to 1 volt/μ bar so we know the gain at 1 m will be:

$$\begin{aligned} &+2 - 64.7 \text{ dB rel 1 volt}/\mu \text{ bar} \\ &= -62.7 \text{ dB rel 1 volt}/\mu \text{ bar} \end{aligned}$$

So for equation 1 the value A takes is:

$$-62.7 \text{ dB rel 1 volt}/\mu \text{ bar}$$

Thus, the receiver can be described as a fixed gain of -62.7 dB rel 1 volt/μ bar with a TVG characteristic of $+20 \log R + 2 \alpha R$ dB, or a complete description of the receiver is given by:

Receiver gain = $-62.7 + 20 \log R + 2 \alpha R$ dB rel 1 volt/μ bar for operation between 5 and 150 m.

However if the required depth of operation had been between 300 and 500 m and the dotted curve had been drawn 3.5 dB lower then the result would be different. In this case the level part of the TVG characteristic would have been at +61.2 dB rel 1 m, or gain at 1 m would be -61.2 dB rel to final gain on TVG characteristic. Thus with VR still measured at +2 dB rel 1 volt/μ bar the value of A would be -59.2 dB rel 1 volt/μ bar. In that case the complete description of the receiver is given by.

Receiver gain = $-59.2 + 20 \log R + 2 \alpha R$ dB rel. 1 volt/μ bar.

There is one final item of information which is relevant and given on Figure II.6. This is the +0.4 dB error at 5 m. The receiver gain description is the one used for a survey where a series of different depths are compared or averaged. But the "calibration" experiment is carried out at a fixed range of 5 m. So, in this case, a small correction of -0.4 dB is applied to the data in order to remove the bias between measured TVG curve and required curve.

The curve fitting is required for the survey and only a fixed factor is required for "calibration" experiments. However, to convert the results of these experiments for use on the survey it is necessary to do both at that point in the work.

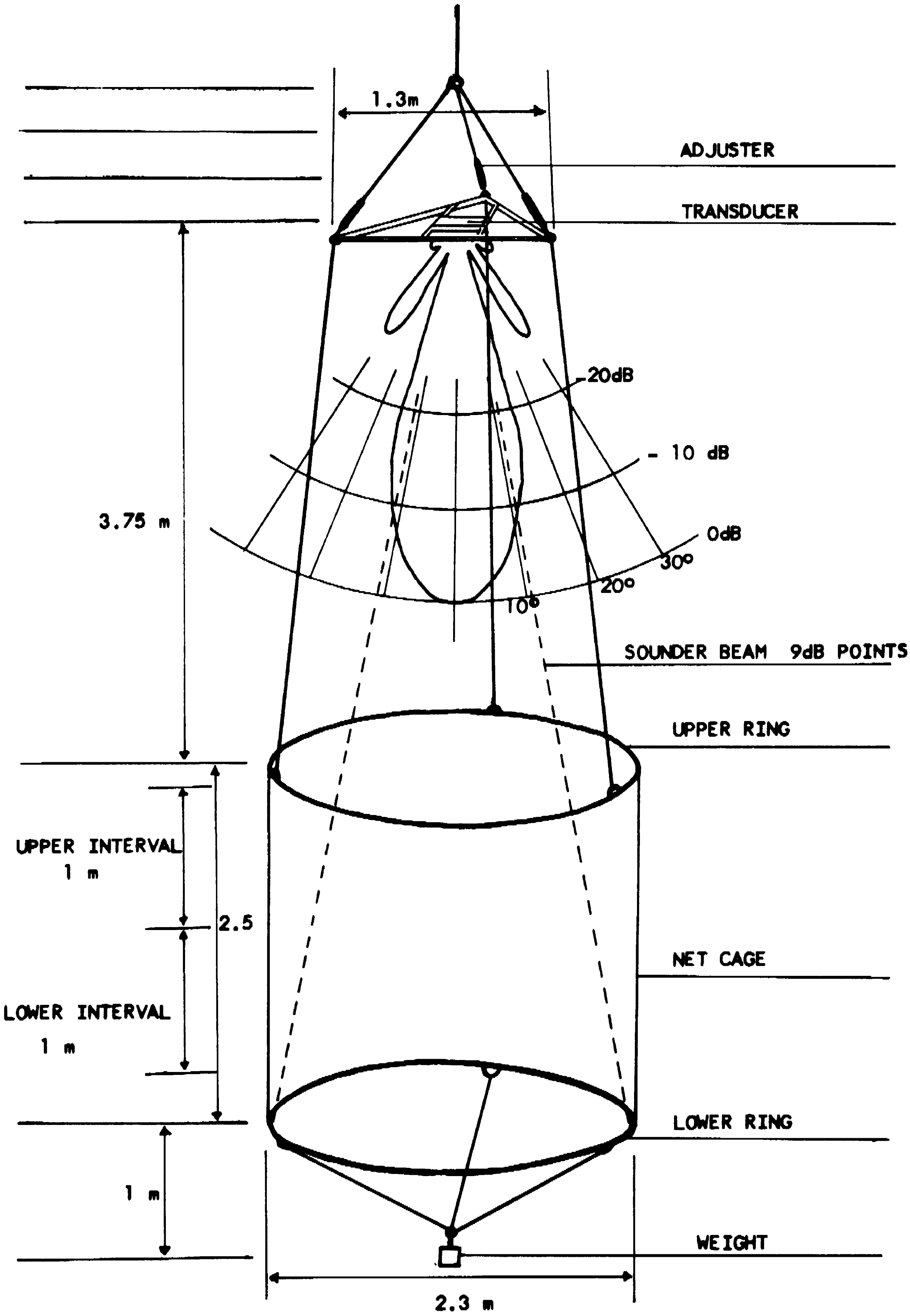
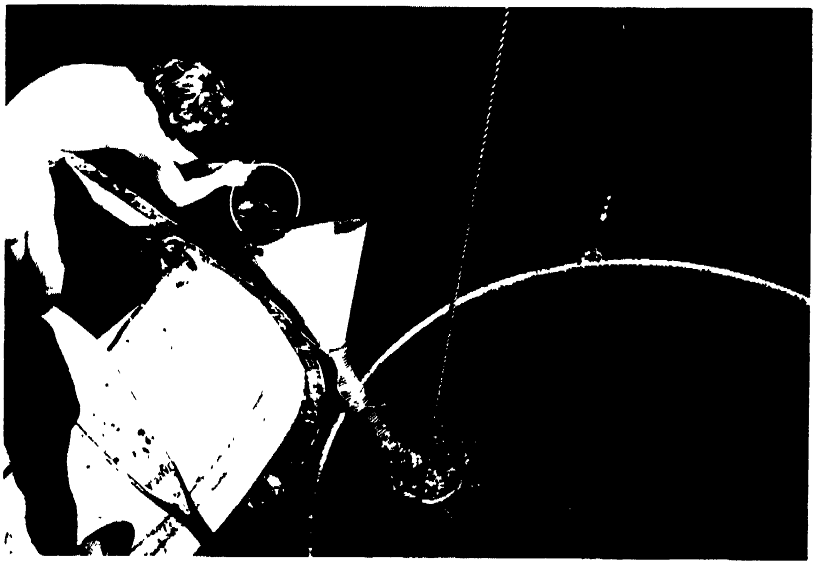


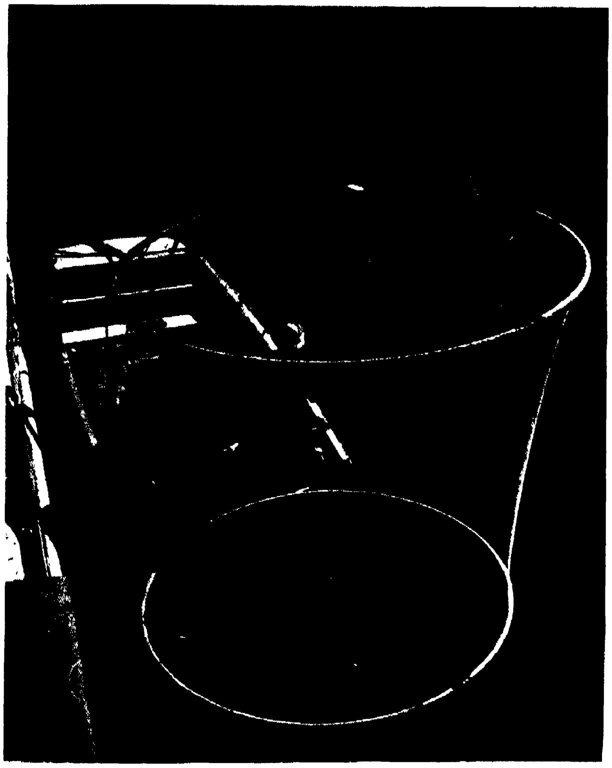
Fig. II.1 - Rig for live fish calibration - Scale:1 m = 3 cm

Photograph 1 - Keep tanks

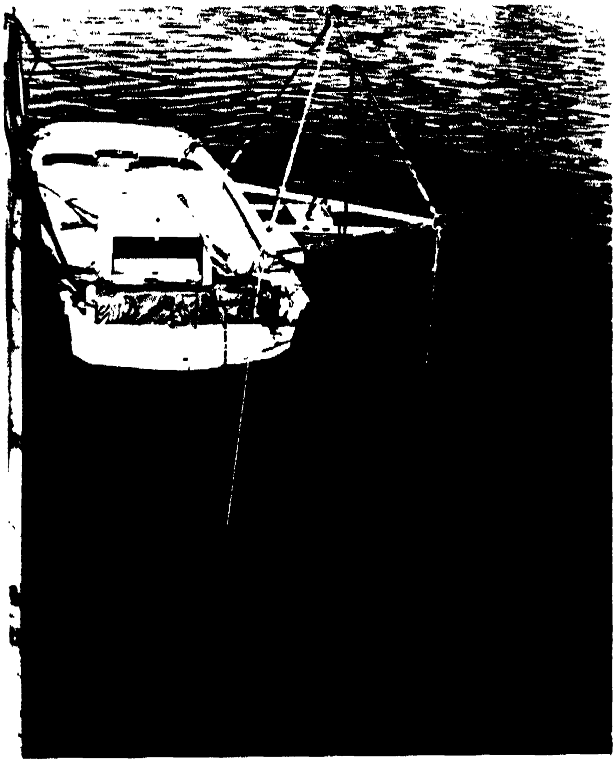
Photograph 2 - Transferring fish by bucket



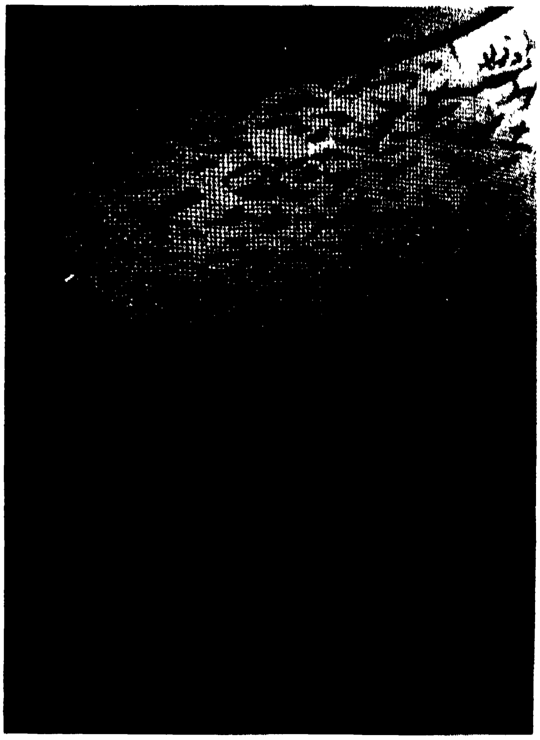
Photograph 3 - Introduction of fish in the cage



Photograph 4 - Net cage and transducer platform being lowered into the water



Photograph 5 - Transducer platform with net cage of operating distance



Photograph 6 - Behaviour check of <u>Sardinella gibbosa</u> in the cage at 8 m

Total Length Frequency Distributions

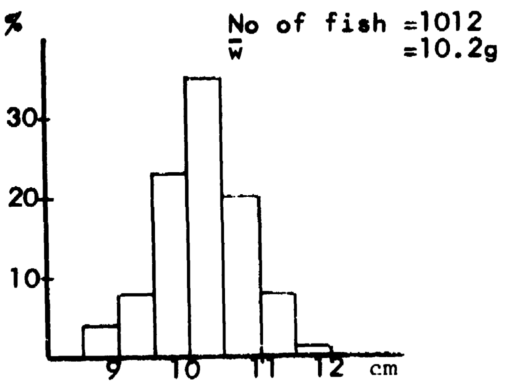


Fig. II.2 - Sardinella sindensis
Experiment 1

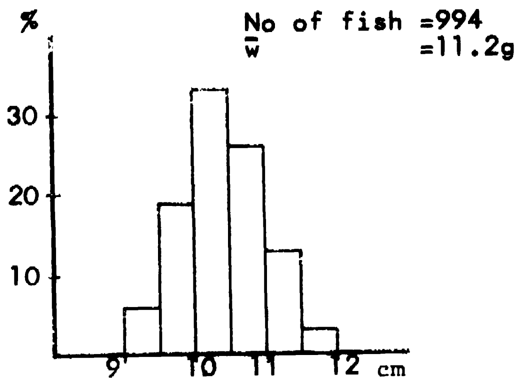


Fig. II.3 - Sardinella sindensis
Experiment 2

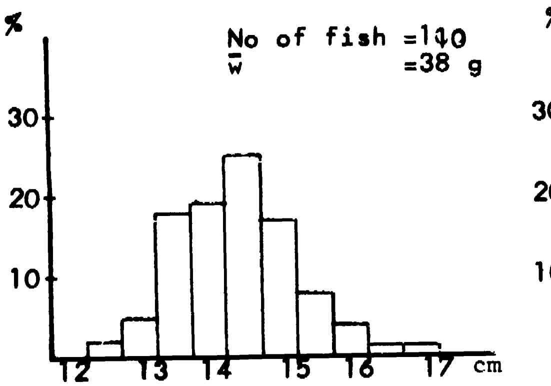


Fig. II.4 - Selar crumenophthalmus
Experiment 3

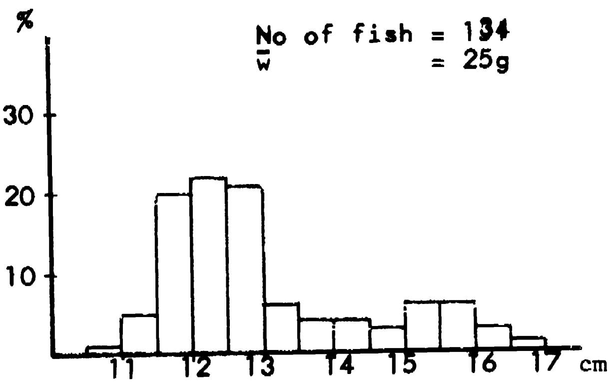


Fig. II.5 - Decapterus kiliche
Experiment 3

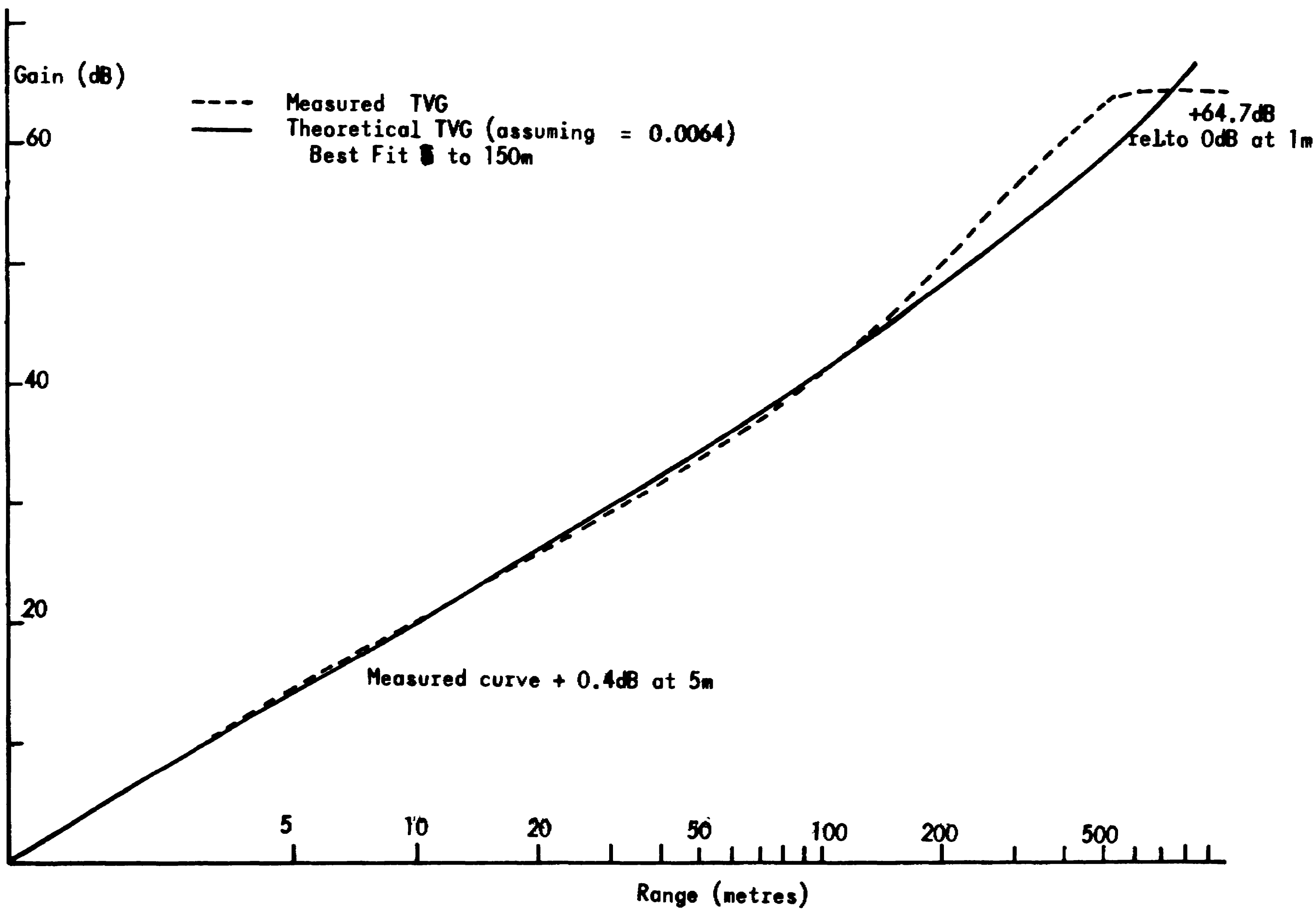


Fig. II.6 - 20logR + 2 R TVG for LEMURU EK-S 38

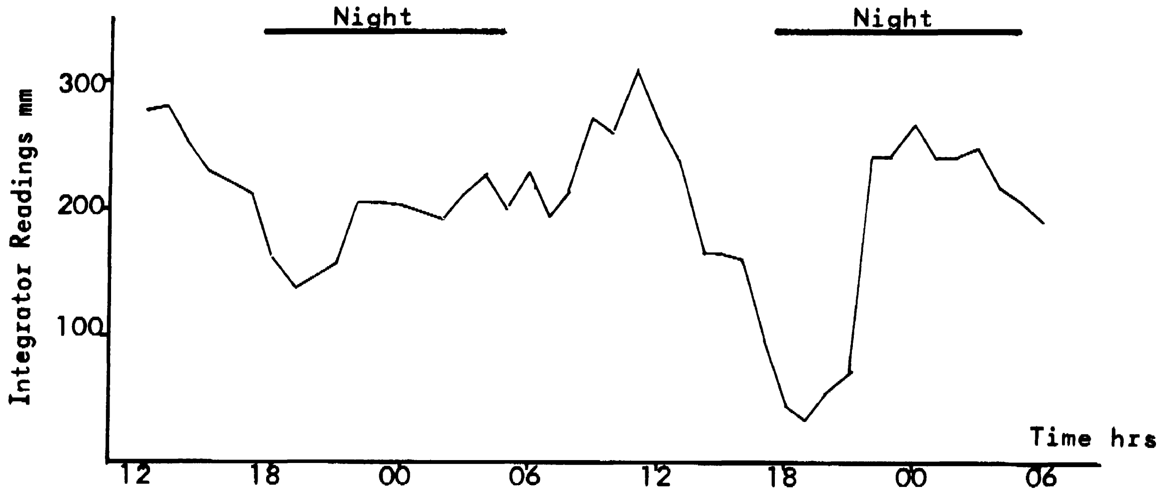


Fig. II.7 Experiment 1 *Sardinella sindensis*

Average Integrator Readings

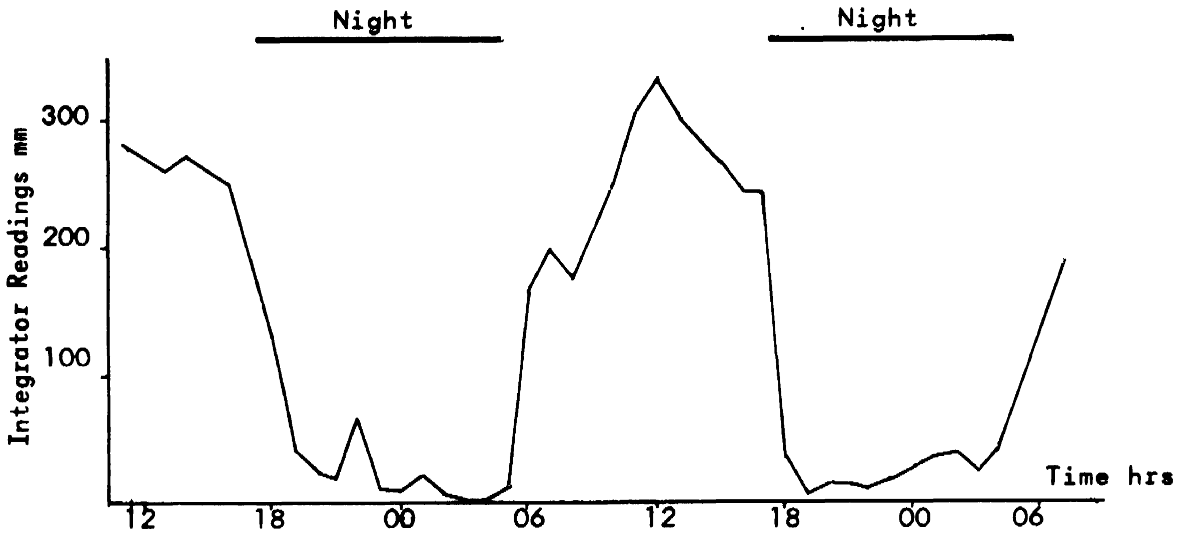


Fig. II.8 Experiment 2 *Sardinella sindensis*

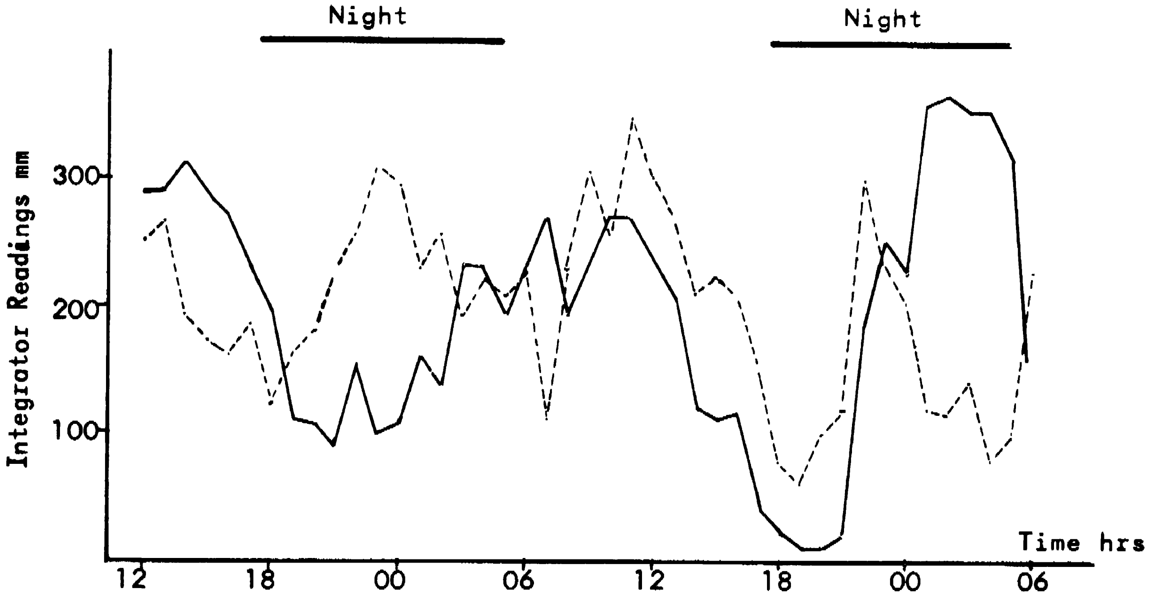


Fig. II.9 Experiment 1 Sardinella sindensis

Interval Readings Plotted Separately

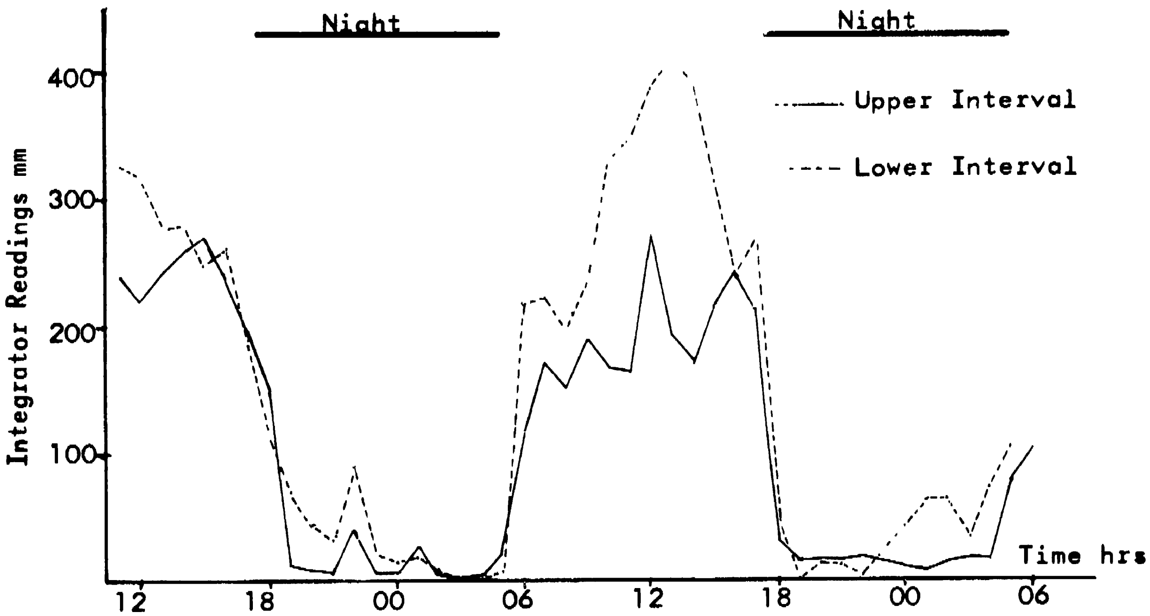


Fig. II.10 Experiment 2 Sardinella sindensis

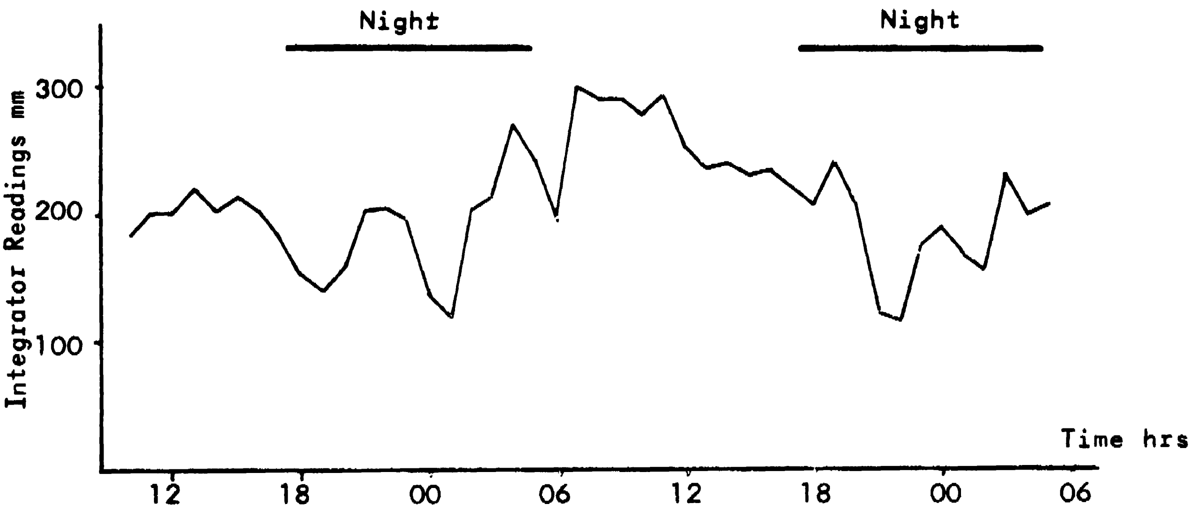


Fig. TI.11 - Experiment 3 Scad and horse mackerel, average integrator readings

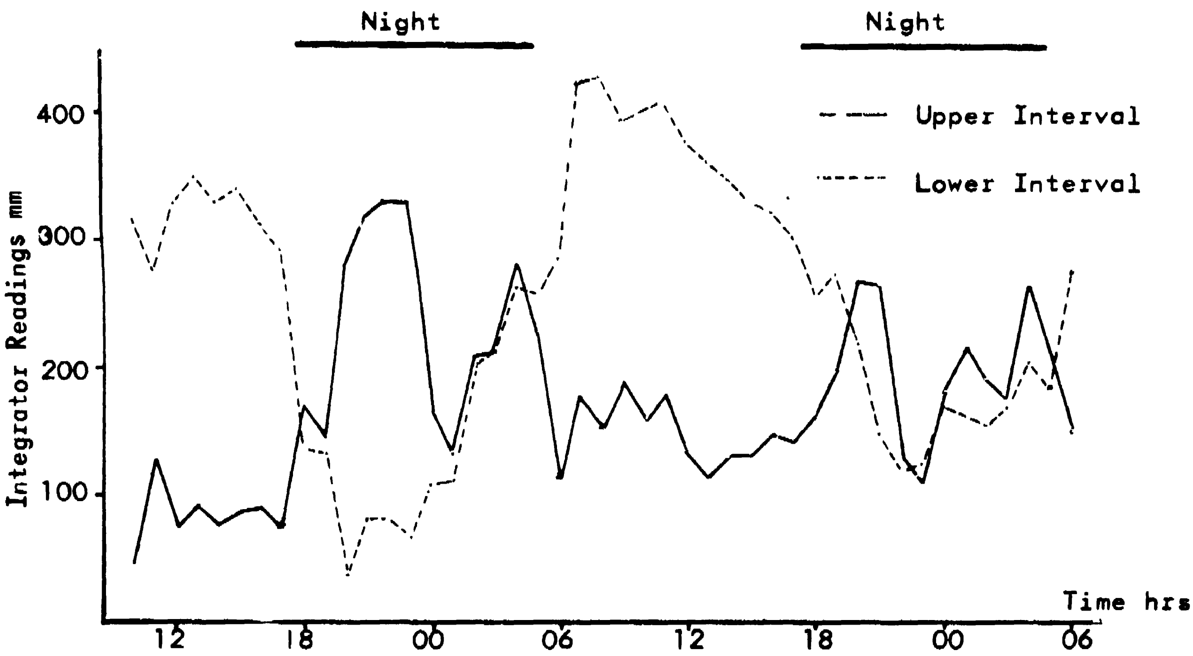


Fig. II.12 - Experiment 3 Scad and horse mackerel interval readings plotted separately

Appendix 3 to Part 3

TRANSMISSION COUNTER TO PROVIDE 1Nm RESET

GENERAL DESCRIPTION

The circuit counts Transmit Pulses from the EKS Sounder. After a preset number have been counted, the circuit provides a reset pulse to the log input of the integrator. The circuit then resets itself, and counts the following transmissions.

DETAILED CIRCUIT DESCRIPTION:

The circuit diagram may be seen in Figure III.1. The counter is formed by three SN74191's connected as a ripple through counter.

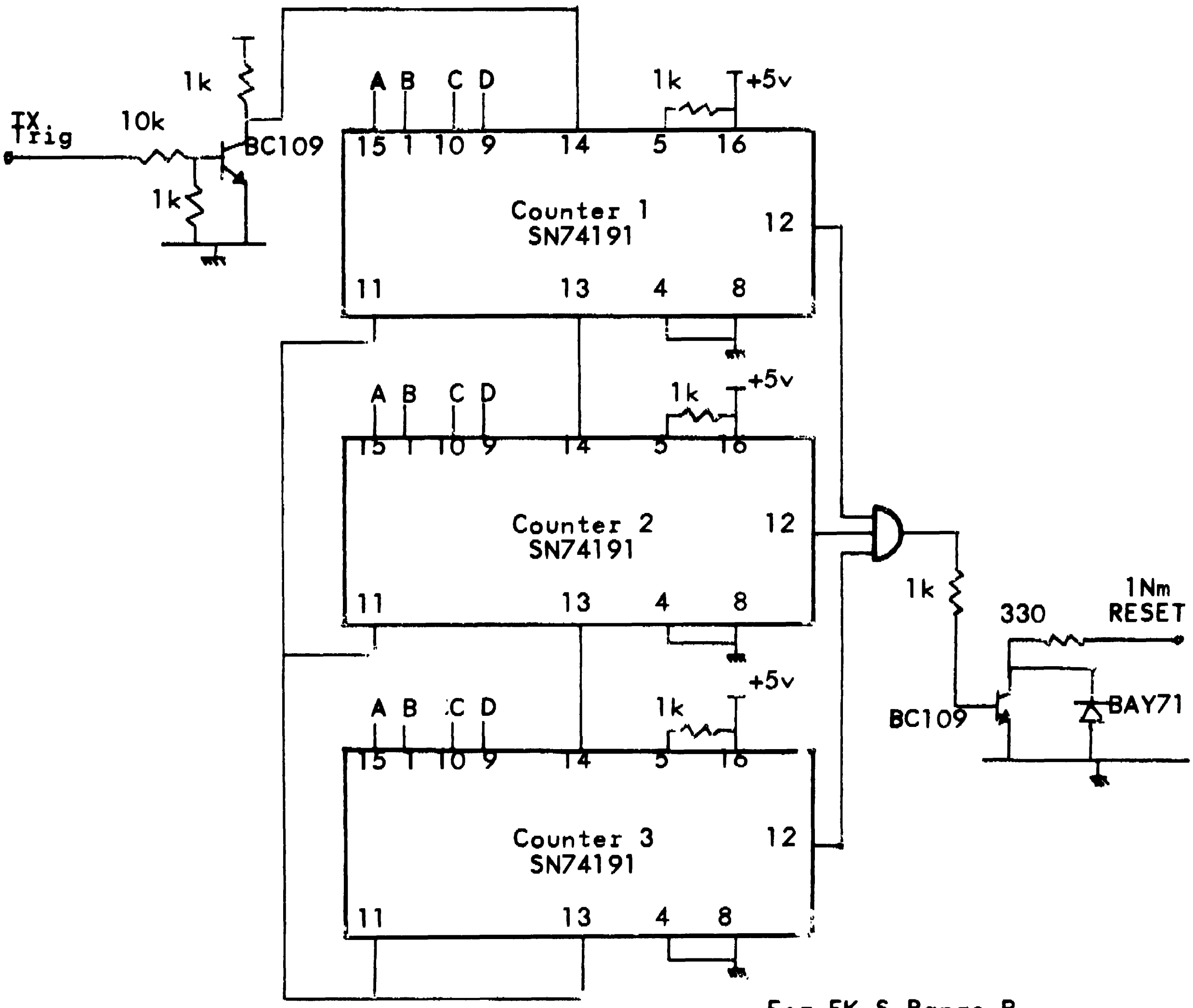
Assuming the counter is counting, it will decrement (pin 5 held high) every transmission when a clock pulse fed to the top counter (pin 14) arrives. The clock is the Transmit Pulse provided by the Sounder, inverted, and reduced to 5 V by the BC109 at the top left of the diagram. When a counter reaches zero the max/min output (pin 12) gives high. When all the counters are zero the outputs gated together drives the BC109, on the right of the diagram, and this resets the integrator.

The following transmission removes the max/min signal and produces ripple clock pulse (pin 13) which is fed to the load input (pin 11) and this loads the value on the A, B, C, D inputs of the counters.

The values used are shown in the table at the bottom right of the figure. This gave a 7 min 34 sec reset.

The power supply is shown on the bottom left of the figure.

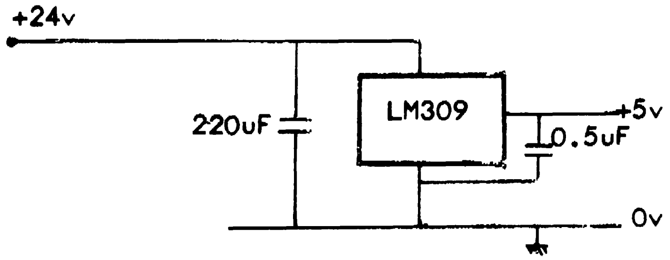
Should the circuit be required to give a different reset period then different values for A, B, C, D inputs may be selected.



For EK S Range B
Speed set 8knot

	A	B	C	D
Counter 1	l	l	h	l
Counter 2	h	h	l	h
Counter 3	h	h	l	l

l=0v h= 1kΩ to +5v



TX Trig	Pin 4 QM Rack Mt
+24v	Pin 18 EK E101
0v	Pin 3 QM Rack Mt
1Nm Reset	Pin 8 QM Rack Mt

Fig. III.1 - Transmission counter to provide 1Nm reset

Appendix 4 to Part 3

DAY/NIGHT COMPARISON EXPERIMENTS

During the survey there were indications that the differences in behaviour of both pelagic and demersal species between day and night might be affecting the relative density readings. A series of day/night comparison experiments were undertaken during July and October 1978 to check if this day/night difference was real, and if so, to determine the magnitude of the effect and investigate the possible causes.

1. METHOD

Six areas were selected (Figure IV.1). Each of these areas was surveyed for a 24-h period using randomized transects. Following the survey, a further 24 h was spent fishing in each area. The results from the fishing operations were used to determine the species compositions of the areas. The survey results were used to determine average relative density values for day and for the night in each area.

After comparing variance which were found to be not significantly different, the values of mean relative density for the day and the night were compared using a Student 't' test. Then, to determine the correct magnitude of the difference, the values were corrected for species composition and then averaged.

2. RESULTS

2.1 Areas I, II and III

Because of their similarity in species composition, these areas are considered together. In all these areas the predominant species was Sardinella sindensis and they were used to determine the day/night compensation factor for this species.

Species Composition (Areas I, II, III) (See Fig. IV.1)

Area - Qatar	Trawl	Total catch (kg)	Sardinella (kg)	Percentage
I - July	1	47.6	43	
	2	306	275	
	3	54.7	38	
		408.3	356	87
Area - Halul				
II - October	1	143	140	
	2	117	114	
	3	160	158	98
		420	412	

Area - Dubai	Trawl	Total catch (kg)	Sardinella (kg)	Percentage
III - October	1	148	142	
	2	249	226	
	3	93	72	
		490	440	90

In Area I the remaining part of the stock was demersal fish which rose from the sea bed at night. In Areas II and III the remaining part of the stock was made up of Selar crumenophthalmus, Decapterus kiliche and Rastrelliger kanagurta.

All the above catch data were obtained from trawl catches carried out at night. Schooling fish are more active during the day, and therefore midwater trawling is not so efficient a method of catching them. Fishing during the day was undertaken using the purse seine net. Because this net catches single schools or parts of a school, it may be used for school identification but not for species composition unless a large number of sets are carried out. The results from the purse seine fishing indicated the same predominance of Sardinella sindensis as shown by the trawling at night.

Mean relative density figures from the echo integrator and 't' values

Area	Day	Night	t
I - Qatar	7.6	14.4	2.3
II - Halul	13.8	24.2	2.4
III - Dubai	12.4	25.0	3.0

All values of 't' are greater than 2.04 and thus there is more than a 95 percent probability that there is a significant difference in the mean day and night values in each area.

In order to determine the difference in the density readings between day and night for Sardinella only, in Area 1 the proportion of the readings due to demersal fish rising from the sea bed during the night have been eliminated. For this purpose, it has been assumed that this group of fish had a back-scattering strength similar to that of Sardinella per unit weight. As Sardinella constituted 87 percent of the midwater catches at night in this area, the density reading for this fish at night becomes 0.87 x 14.4 = 12.5.

The species other than Sardinella present in midwater in Areas II and III were a mixture of horse and scad mackerel. These species were a small proportion of the total and were present in midwater, both during the day and the night. Their behaviour is not known accurately and it is assumed that they follow a similar behaviour pattern to the sardine. Because of this, they have been included along with the Sardinella for the purpose of this calculation. At any rate, because of the small amount of these species, their behaviour would have affected the total density readings insignificantly.

Using these values from above to obtain a day/night ratio for each area, the following results are obtained:

Area	Day:Night Ratio
I	1:1.65
II	1:1.75
III	1:2.02

Because the mean of the day and the night are significantly different in each area, these three values can be averaged.

Average correction factor for day-time integrator readings

$$= 1.80/_1 \quad \text{(for } \underline{\text{Sardinella}}\ \underline{\text{sindensis}}\text{)}$$

2.2 Areas IV, V and VI

The results from these areas are disappointing. In October 1978, in Areas V and VI, the catches contained adult Stolephorus during the day, and a mixture of Stolephorus sp. and Leiognathus sp. during the night, but in addition there were a large number of Stolephorus and Thryssa larvae. The fish, much too small to be retained by the meshes, were found on the twine of the net and the numbers found suggested very large quantities in the sea. These observations, together with very high integrator readings, indicated that the proportion of these larvae in the recordings must have been high. This made it impossible to determine the species composition, required for Leiognathus, from the night readings. Therefore, no day-night comparison was possible in these October experiments.

In Area IV, during July 1978 the situation was slightly better. Here the day-time stock was predominantly adult Stolephorus sp. joined by a substantial amount of Leiognathus sp. rising from the bottom at night. Again the accurate determination of the relative proportions was hampered by escapement of Stolephorus through the meshes of the trawl and hence the results were not reliable for determining species composition in the area. The results were inconclusive but did show strong indication that no day-night compensation was required for the behaviour of Stolephorus sp.

3. DISCUSSION AND CONCLUSION

During the three seasonal coverages, the differences in mean density values between day and night integrator readings indicated evidence of similarity with the results of these specific day-night experiments. This was observed particularly for areas where Sardinella sindensis was present.

Since the determination of the conversion factor for S. sindensis was the result of three experiments, carried out in different areas and in two different seasons, and there was no significant difference between these areas and seasons, it was considered reliable enough to apply the value 1.8 to all survey coverage in respect of this species. However, in the case of Stolephorus sp. no conversion factor has been applied.

It should be remembered that if a day-night compensation is required for Stolephorus the effect of this will be to increase the stock estimate. Therefore, by not applying a factor to this species group there is a possibility that the stock is slightly underestimated.

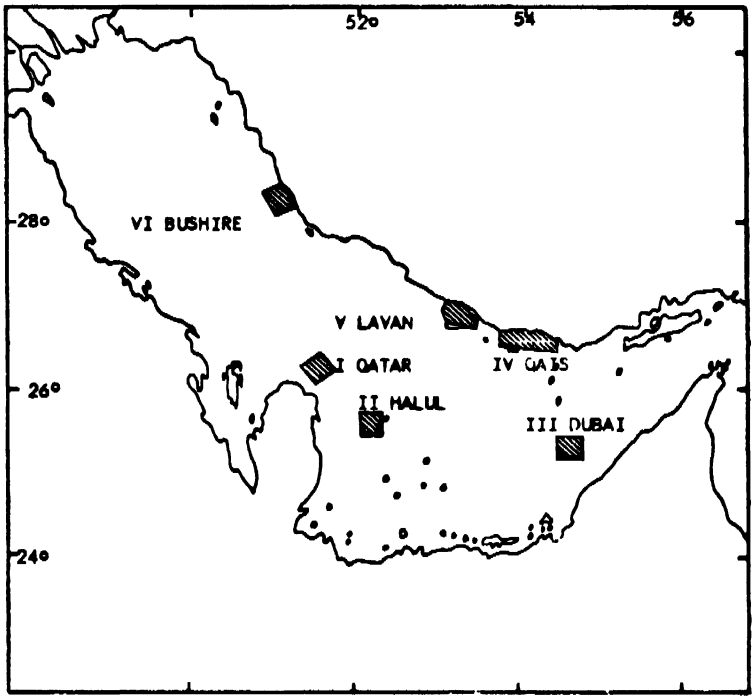


Fig. IV.1 - Location of the day-night experiment areas

4. RESULTS OF THE PURSE-SEINING OPERATIONS CARRIED OUT BY THE RAS AL KHAIMAH FISHING COMPANY BETWEEN NOVEMBER 1976 AND DECEMBER 1977

by

W.J. Scheffers

ACKNOWLEDGEMENTS

The author wishes to express his gratitude to His Highness Sheikh Khalid bin Saqr Al Qasimi, Crown Prince and Deputy Ruler of Emirate Ras Al Khaimah, for his permission to publish the data from the Ras Al Khaimah Fishing Company. Thanks are due to Mr M. Edwards, Technical Adviser to the Government of Ras Al Khaimah for his advice, to Mr T. Kroepelien, Managing Director of the Ras Al Khaimah Fishing Company for information concerning the operations, to Mr Erlingson, Fleet Manager, and to the staff of the Ras Al Khaimah Fishing Company.

Special mention should also be made of colleagues who rendered invaluable assistance in translating records from Icelandic and Norwegian into English and by providing guidance during the preparation of this report.

4.1 INTRODUCTION

The Ras Al Khaimah Fishing Company was founded by H.H. Sheikh Saqr Bin Mohammed Al Qasimi, Ruler of Ras Al Khaimah, which is one of the seven United Arab Emirates. The Company operated a fleet of seven purse-seiner (RAK I-RAK VII) from the port at Mina Saqr in order to supply raw material for a fishmeal plant (Atlas, capacity 10 t/h) at Shams, about 30 km north of the city Ras Al Khaimah. Operations started in November 1976. Due to an insufficient supply of raw material the Company could not continue operating the fishmeal plant, and activities had to be stopped in January 1978. During its operation main emphasis had been on purse-seining for small pelagic species, particularly sardines, but bottom trawling had also been attempted. The reasons for discontinuing operations became evident from the quarterly reports from the Managing Director of the Company which are summarized below:

The supply of fish was far below the target and this failure was attributed to an overestimation of the quantity of fish available in the waters off Ras Al Khaimah. Following poor fishing during December 1976 and January 1977, one of the vessels changed to bottom trawling. The other vessels continued purse-seining, expecting to obtain better information on resources available for industrial purposes. In order to obtain this information a marine scientist was recruited to register all available information on fishing operations and biological data on the fish caught.

During the period March-May 1977 production showed improvement over that of the preceding quarter, but the target of 3 600 t/month was not reached. The delay in the arrival of some of the vessels and the lack of an ice plant were considered to be some of the limiting factors. The last vessel arrived in May. It became evident that other factors also contributed to the poor results, such as the design of the purse-seine and the restrictions on operating in better fishing areas north of Khow Khwair. Consequently the purse-seine was modified.

The situation prompted the Company to investigate the possibilities of utilizing the catch as fresh fish for human consumption and for types of animal feed other than fishmeal, in order to improve the economics of the whole operation.

Investigations in late May and June 1977 once more reported disappointing results, and there were indications that the fish had moved closer to the bottom, both in the Gulf and the Gulf of Oman. Between June and August 1977 the production again did not reach the target. After reviewing the progress the Company doubted the validity of the feasibility study which had forecasted an annual production of 42 000 t.

Additional problems were considered to have caused loss of fishing time and a corresponding decrease in the production. These were:

(a) the normal teething problems during an initial period of operation with insufficiently experienced crew;

(b) insufficient stocks of spare parts;

(c) frequent breakdowns of electronic equipment, due to the adverse climatic conditions.

During the entire period crew problems also hampered the efficiency of the operations. At the beginning it was difficult to recruit Norwegian skippers because of the good fishing season in Europe, and later the high cost of Norwegian skippers resulted in their replacement by Icelanders. Following this problem, the European engineers were also replaced.

During the total operational period the fleet landed about 5 000 t of fish. By the end of November 1977, 1 063 t of fishmeal had been produced (18.5% of the total supply of raw material), of which 211 t (4 241 bags) were exported and 851 t (17 023 bags) remained in store. At the end of 1977, 228 t of fishmeal and 10 500 gall of fishoil remained in store.

4.2 THE DATA

The data for the present report have been extracted from captains' logbooks, fishing log sheets and consignment forms. In general, observations in the captains' logbooks had been written in Icelandic or Norwegian and had to be translated. The fishing log sheets gave information on: set, type of gear, date and time of setting the net, duration of the tow (in the case of the bottom trawl), depth and area of fishing, sea-temperature, weight and composition of the catch, deviations from the normal programme and unusual observations of fish behaviour.

There was an overlap in the information provided by the captains' logbooks and the fishing log sheets, but in many instances the records were still incomplete. Though it had been recommended to record surface temperatures, this was not done. The consignment forms gave the exact weight of the landings.

Wherever the time spent at sea could not be extracted an estimate has been made. Time spent on any activities other than sailing to the fishing ground, scouting and fishing, has been classified under "others" and this includes time at anchor, drifting at night, salvaging, and research. The duration of each trip has been classified as follows:

0- 6 h	=	1/2 day trip
6-24 h	=	1 day trip
24-48 h	=	2 day trip
48-72 h	=	3 day trip
72-96 h	=	4 day trip

If during one day a vessel went out and returned twice, this has been recorded as two 1/2-day trips, regardless of the duration of the time spent at sea in each instance.

Nearly all fishing operations were carried out during the day, but in some cases the time of setting has not been recorded. Sets without catches have been indicated and it has also been indicated when no catches were made because of operational problems.

The catch from each set was estimated by the captain. In cases where the main species caught was not sardine, the composition of the catch has not always been recorded.

The actual landings have been recorded on the consignment forms and were filled in on the daily record forms, i.e., these data represent the catches of one or more trips and only occasionally provided the result of one single fishing day.

The fishing ground was divided into three sectors as illustrated in Fig. 4.1 and Table 4.1.

Table 4.1

THE MAIN FISHING AREAS COVERED BY THE VESSELS

Sector	I	II	IIIa	IIIb
Location	North of Ras Al Khaimah	South of Ras Al Khaimah	Around Mubarek Oilfield	Towards the Oman border
Approximate surface in n.mi^2	400	350	450	475

Fishing was generally done at a depth around 20 fathoms (≈ 36 m, 1 fath = 1.8288 m)

The variations in the production pattern were analysed for all vessels collectively, as well as for individual vessels. Only the results of the purse-seining operation are discussed in this report. Information from the experimental bottom trawling and the catches of larger pelagics have been incorporated in the report on the demersal resources (see FAO, in press, and part 5 of this report).

4.3 THE FLEET AND ITS OPERATIONS

4.3.1 Specification of the Vessels and the Gear Used

The vessels were of steel and 75 ft long. The machinery and electronic equipment of the 7 vessels (RAK I-RAK VII) were similar and as follows:

Main engine	Caterpillar D 343, HP 365
Auxiliary engine	Ford 4DF 4121
Generators	Onan 25.0 MDEH.515R/3316G
Winch RAK 1-5	Stroudburg 530 DD
Winch RAK 6 and 7	Hydraulic Marco W 1160
Power block	Marco Mod. 28H
Fish pump	RAFP 8" U 231
Radar	Decca 110
Sonar	Simrad
Echosounder	Simrad EL
Scope	Simrad 95 C/1
Radio	Sailor RT.144

The purse-seine originally used had a length of 220 fath, depth 22 fath, mesh size 19.6 mm (stretched) and was weighed with 800 kg lead. In May 1977 one net was made larger and deeper (length 270 fath, depth 40 fath, weighed with 1 200-1 300 kg lead), but this did not result in a significantly better performance. Between June and August 1977 two nets were made slightly deeper than the original depth (length 220 fath, depth 30 fath, with 1 100 kg lead) and according to the information, this resulted in a more efficient performance. The design of this modified purse-seine is given in Fig. 4.2.

4.3.2 Operations

Purse-seining started in November 1976 and ended in December 1977. Table 4.2 shows the operational period and the number of fishing days per month for each of the vessels.

In total the vessels spent approximately 907 days at sea sailing, scouting or fishing. However, the exact number of days spent at sea could not be determined because the available records were not complete. In particular the data for November 1976 were not clear and had to be disregarded. During December 1977 only the first 10 days were utilized for sardine fishing and the rest of the month was devoted to tuna fishing.

The average number of days at sea varied very little between vessels and was around 16.5 days/month/vessel. Due to insufficient records for RAK I in November 1976, RAK IV in June 1977 and RAK VI in December 1977,the data for these periods have been excluded from the calculation of the averages.

A total of 703 vessel-days were spent in port, of which only 4.4% was due to bad weather and nearly 38% due to repairs. The remaining 57.6% was for holidays and other unknown reasons. The time spent in port appeared to be relatively higher during the winter months. The average number of days in port for individual vessels varied from 10 to 16 days.

Time lost at sea due to bad weather and technical problems could not be identified and is therefore included in the days at sea. However, of the estimated 10 674 h spent at sea by all the vessels together, about 11.4% could be considered as used on activities other than sailing, scouting or fishing. Each vessel on the average spent 194 h/month at sea and lost 22 h on activities other than sailing, scouting or fishing.

The seven vessels made a total of 804 fishing trips (Table 4.3) of which about 83% were of a duration less than 24 h (half-day and day trips). This percentage varied between 60% in March 1977 and 99% in November 1977. Among the reasons considered responsible for this variation the following should be mentioned:

(a) the distribution of fish in the area and the school size;

(b) the lack of ice onboard;

(c) the necessity for raw material to be supplied to the factory;

(d) technical problems with the vessels;

(e) gear damage.

For the whole period the average duration of a trip was about 13 h. Between March and July 1977 the average duration of a trip appeared to be higher (16-20 h) and from June to September, when the sea temperature is high, the duration of the trips decreased, probably due to lack of ice onboard.

Table 4.4 shows that a total of 1 672 sets have been recorded, of which 1 008 (60%) were effective in catching and 648 (39%) without result, of which 69 sets were ineffective due to technical failures. On average the vessels made about 2 sets/day.

The percentage of effective sets was low in the first few months, but improved considerably after January 1977 and varied between 53% (June, July) and 76% (May). There was no evidence of a significant difference in the average number of sets per day between vessels.

According to the reports, three extensive research cruises have been executed during May and June 1977, with one vessel in the area between Ras Al Khaimah and Dubai, and with three or four vessels in the area between Dubai and Bahrain. From these investigations it has been concluded that the fish were thinly dispersed near the bottom in the Gulf and the east coast of the UAE, and that it was not possible to catch them by purse-seine under such circumstances.

Table 4.2

NUMBER OF DAYS AT SEA PER VESSEL, RAS AL KHAIMAH, DECEMBER 1976 - DECEMBER 1977

Vessel		Arrival of vessel	Days at sea													Total period	No. of months of operation	Vessel average (days at sea)
			Dec. 1976	Jan. 1977	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.			
RAK I		Mid Oct. 1976	15	16	Trawling	1-10 Trawling 16	19	-	2	12	13	18	11-31 Trawling 8	Trawling	1-13 Trawling	119 (?)	9	13.0
RAK II		Mid Oct. 1976	19	20	23	17	15	27	17	23	15	-	12	19	5	212	12	17.5
RAK III		End of Nov 1976	-	13	19	23	24	26	20	10	18	19	22	18	7	219	12	18.0
RAK IV		Late Jan. 1977	-	-	-	-	-	12+?	No records	16+?	19	20	23	10+?	-	100 (?)	6	16.5 (?)
RAK V		Expected arrival 11.4.77	-	-	-	-	-	-	8	15	22	17	9	-	-	71	5	14.0
RAK VI		Beginning of May 1977	-	-	-	-	-	-	11	13	16	22	15		No records	77	5	15.5
RAK VII		Beginning of May 1977	-	-	-	-	-	-	?	13	27	24	22	18	5	109	6	18.0
Total No. of:	Vessels		2	3	2	3	3	3	5(6)	7	7	6	7	4	3 (4)	55 (58)	55	16.5
	Days		34	49	42	56	58	65(?)	58	102(?)	130	120	111	65(?)	17	907 (?)		
Average No. of of days at sea per vessel			17	16.5	21	18.5	19.5	21.5	11.5	14.5	18.5	20	16	16	5.6	16.5		

Table 4.3

MONTHLY NUMBER AND PERCENTAGES OF TRIPS BY DURATION AND MONTHLY AVERAGE DURATION OF TRIPS - RAS AL KHAIMAH, DECEMBER 1976-DECEMBER 1977

Date	No. of trips					Total time spent at sea (h)	Average duration of a trip (h)	Percentages			
	Total	1/2 day trip	1 day trip	2 day trip	3 day trip			1/2 day trip	1 day trip	2 day trip	3 day trip
November 1976	-	?	?	?	?	?	?				
December	33	2	30	1	-	388	12	6	91	3	-
January 1977	52	13	37	2	-	487	9	25	71	4	-
February	37	6	24	7	-	475	13	16	65	19	-
March	40	10	14	12	4	740	18	25	35	30	10
April	46	13	17	15	1	751	16	28	37	33	2
May	58	8	42	8	-	675	12	14	72	14	-
June	45	5	23	13	4	900	20	11	51	29	9
July	80 1/	10	51	16	3	1 303	16	13	64	20	4
August	111	29	59	18	5	1 484	13	26	53	16	5
September	116	26	80	10	-	1 321	11	22	69	9	-
October	99	15	70	13	1	1 265	13	15	71	13	1
November	65	16	48	1	-	640	10	25	74	2	-
December	21	6	12	2	-	245	12	29	62	10	-
	804	159	508	118	18	10 674	13	20	63	15	2

1/ one 4-day trip

4.4 RESULTS

4.4.1 The Landings

During the purse-seine operations a total of 5 069 t of fish were landed by all vessels. The landings were mainly composed of sardines (*Sardinella* spp.), followed by mackerels (*Rastrelliger*), scads (*Decapterus* sp.), and hairtails (*Trichiurus* sp.).

Between June and August part of the landings, particularly fish other than sardines, were sold to the market in Dubai and Abu Dhabi through "middlemen", but this scheme did not work well during the Ramadan and was later suspended. These landings have not been well recorded and hence are difficult to link up with the fishing operations. They have, therefore, been ignored, except for the landings of tuna and sailfish, which have been included in the report on the larger pelagics (part 5).

Table 4.5 presents the estimated catches and actual landings for each of the vessels as well as the totals. The estimated catch has been obtained by totalling the tonnage of the catches per set, as estimated by the captains of the vessels recorded in the logbooks. The data of the actual landings have been taken from the consignment forms, with adjustments for the catches made during any particular month which were landed during the subsequent month.

It is evident that there is a high degree of variability in the landings by each of the vessels, partly due to differences in the number of operational days and operational periods. The average landing per vessel per day was 5.3 t. Except for RAK V (average 2.96 t/day) the other vessels had a daily average between 4.3 and 7.0 t

4.4.2 Catch-rates

Fig. 4.3 presents the frequency of the catch per set for all the vessels during the operational period. The average value was 2.9 t/set. Peak mode appears at 2-3 t and lesser modes are found at 5 and 10 t/set. These lesser modes are probably artificial. High frequencies at 5 and 10 t are probably due to an estimation bias, 5 and 10 being "round" figures (see also "peaks" at 15 and 20 t). The individual vessels show some differences in this respect, but these may have been caused by the differences in the seasons of their operation and their total duration of operation.

It appears that in 91% of the sets the catch was from 0 to 10 t, whereas in 9% of the cases the catch was over 10 t. Since the number of hours spent on sailing, scouting or fishing is known it is possible to calculate the average catch/h and a value of 510 kg/h was obtained.

The actual landings were only higher than the captain's estimates during a few months at the beginning of the period. Later, the estimated catch was usually a little higher than the landings but never more than 10% (Table 4.6).

4.4.3 Seasonal Variation

The maximum total landing was observed in May 1977 (724 t) and the minimum in January 1977, while in both months only three vessels were operating. But in June 1977 the monthly landings dropped even though six vessels were operating. From July 1977 the monthly landings increased again to reach a maximum in November 1977 when only four vessels were fishing. In the beginning of December 1977 only three vessels were operating and after 10 December the fishing for sardines was stopped.

Table 4.4

DETAILS OF THE NUMBER OF SETS MADE WITH AND WITHOUT CATCHES, IN RELATION TO THE NUMBER OF VESSELS OPERATING, RAS AL KHAIMAH, NOVEMBER 1976 - DECEMBER 1977

Date	No. of sets				Percentages			No. of vessels operating (with records)	Monthly average No. of sets per vessel	No. of days operating	Average daily No. of sets per vessel
	Total	With catch	Without catch	Without 1/ catch technical failure	With catch	Without catch	Without 1/ catch technical failure				
November 1976	?	?	?	?	?	?	?	?	?		
December	32	7	22	3	22	69	9	2	16	34	0.9
January 1977	40	10	22	8	25	55	20	3	13	49	0.8
February	48	27	16	5	56	33	10	2	24	42	1.1
March	100	57	40	3	57	40	3	3	33	56	1.8
April	94	59	31	4	63	33	4	3	31	58	1.6
May	119	91	27	1	76	23	1	3	40	65	1.8
June	76	40	29	7	53	38	9	5	15	58	1.3
July	204	108	92	4	53	45	2	7	29	102	2.0
August	256	155	94	7	60	37	3	7	37	130	2.0
September	296	182	97	9	61	33	3	6	49	120	2.5
October	226	155	59	12	69	26	5	7	32	111	2.0
November	153	100	41	4	65	27	3	4	38	65	2.4
December	28	17	9	2	61	32	7	3	9	17	1.4
	1 672	1 008	579	69	60	35	4	55	30	907	1.8

1/ Sets without catch, due to a technical failure are included in the column "without catch"

Table 4.5

TOTAL ESTIMATED CATCHES AND ACTUAL LANDINGS, MONTHLY AND DAILY AVERAGES FOR ALL VESSELS, RAS AL KHAIMAH, NOVEMBER 1976 - December 1977

Vessel	Estimated catch (t) (Captain's estimate)	Actual total landings (t)	Actual landings during observation period (t)	No. of days operating	No. of months operating	Daily average (t)
RAK I	472.8	599.5	513.4[1/]	119	9	4.3
RAK II	1 128.9	1 125.3	1 124.9	212	12	5.3
RAK III	1 333.0	1 237.7	1 216.1	219	12	5.6
RAK IV	624.3	695.6	568.4	100	6	5.7
RAK V	245.5	210.4	210.4	71	5	3.0
RAK VI	477.0	433.4	428.2	77	5	5.6
RAK VII	?	767.2	767.2	109	6	7.0
Total	5 075.0	5 069.2	4 828.7	907	55	5.3

1/ Landings of November 1976 (55 t) included

Fig. 4.4 presents the frequencies of the catch per set for each month of operation. It can be observed that the modes for each month show more or less the same pattern as that for the whole period (Fig. 4.3). However, between January and April the percentage of the catches with about 10 t/set increased rapidly, then declined and remained steady until October and then increased again to December, which seems to imply a denser schooling during the colder months.

Fig. 4.5 presents the seasonal variation in the average catch/set. It shows a value of 2.2 t/set in January 1977, increasing to 7 t/set during March, April and May, declining to around 4 t/set from July to October and then increasing to 9.2 t/set in December 1977 (Table 4.6). It is obvious that the occurrence of denser or larger schools has significant influence on these monthly averages.

4.4.4 Distribution of the Catch over the Fishing Areas

The monthly catches were distributed over the fishing sectors as defined in Table 4.1 and Fig. 4.1. The sets for which the sectors were not mentioned have been grouped under the category "non-defined". Over the whole period, about 55% of the sets were made in Sector I and more than 83% of the effort was made in this area during February, whereas in July and August a higher effort was made in the other sectors combined. During August the fishing grounds were not defined in 25% of the sets (Table 4.7).

For the monthly catch per sector the estimated catches have been used. Not for all fishing operations had the position been specified; therefore the monthly total for the three sectors is different from the estimated total monthly catch. Table 4.8 shows that during the whole period 63% of the catch came out of Sector I, 25% from Sector II and 11% from Sector III. In Sector II the catch exceeded 50% of the total only in April 1977 whereas in Sector III the highest percentage was 29% during July.

Table 4.9 and Fig. 4.3 present the estimated monthly catch and the monthly average per set for the three sectors. They show that the seasonal variation is similar in all three sectors and that no significant differences in the catch rates could be anticipated, though Sector II was slightly better than the other two. However, the fishing effort has been concentrated in Sector I, the shallow waters closest to Ras Al Khaimah.

4.5 BIOLOGICAL SAMPLING OF THE CATCH

According to the instructions the fishermen took from certain catches a sample of approximately 5 kg. This was put in a plastic bag together with a tag giving details such as name of vessel, number of set, date, area code, and upon arrival delivered to the laboratory. Samples of a catch were taken only when the composition or the length distribution of the catch were considered to be different from that of the previous one. Thus, the total of the samples is not representative for the total catch, because the samples were not taken at random.

In the laboratory the sample was analysed and the results were entered on a Fish Sample Form to which was added the fat content (in percentages) of the fish sample.

Though the fishing operations of the Ras Al Khaimah Fishing Company started at the end of November 1976 and continued until the beginning of December 1977, the sampling of the catches unfortunately started only from February 1977, which leaves a gap of two months in the annual cycle.

A total of 337 samples had been collected and analysed during that period (Table 4.10), of which 300 samples (89%) consisted of the species Sardinella longiceps and Sardinella sindensis. A small number of samples have been obtained from Rastrelliger kanagurta, Sardinella perforata and Mulloidichthys auriflamma and only a few from 8 other species, mostly bigger fish from the by-catch.

Table 4.6

MONTHLY TOTAL LANDINGS AND AVERAGE CATCH PER VESSEL BY MONTH AND BY DAY

Date	Estimated catch (t)	Actual total landings (catch) (t)	Actual landings during observation period (t)	No. of vessels operating	No. of fishing days	Average monthly catch per vessel (t)	Average daily catch per vessel (t)
November 1976		55 000		1	2		
December	26.0	83 365	63 365	2	34	31 683	1 864
January 1977	18.7	26 280	15 200	3	49	5 067	0 310
February	131.5	180 550	169 030	2	42	84 515	4 025
March	396.8	393 995	393 995	3	56	131 332	7 036
April	424.0	433 870	433 870	3	58	144 623	7 481
May	650.5	723 420	674 620	3	65	224 873	10 379
June	195.9	249 800	174 200	5	58	34 840	3 003
July	454.3	420 800	420 800	7	102	60 114	4 125
August	639.4	549 440	549 440	7	130	78 491	4 226
September	693.7	575 300	575 300	6	120	95 883	4 794
October	619.5	588 100	578 000	7	111	82 571	5 207
November	668.7	627 650	624 850	4	65	156 213	9 613
December	156.0	161 650	156 000	3	17	52 000	9 176
Total	5 075.0	5 069 220	4 828 670	55	907	87 794	5 324

Table 4.7

MONTHLY NUMBER OF SETS PER SECTOR, RAS AL KHAIMAH, DECEMBER 1976 - DECEMBER 1977

Date	I		II		IIIa		IIIb		Non-defined		Total Area
	No. of sets	(%)	No. of sets	(%)	No. of sets	(%)	No. of sets	(%)	No. of sets	(%)	No. of sets
December 1976	-	-	-	-	-	-	-	-	32	100	32
January 1977	1	3	-	-	-	-	-	-	39	98	40
February	40	83	1	2	-	-	4	8	3	6	48
March	50	50	12	12	7	7	1	1	30	30	100
April	49	52	28	30	-	-	-	-	17	18	94
May	85	71	20	17	-	-	7	6	7	6	119
June	47	62	11	14	-	-	4	5	14	18	76
July	87	43	56	27	36	18	14	7	10	5	204
August	84	33	75	29	19	7	13	5	65	25	256
September	200	68	36	12	12	4	10	3	38	13	296
October	161	71	11	5	5	2	15	7	34	15	226
November	87	57	30	20	5	3	10	7	25	16	153
December	22	79	1	4	-	-	-	-	5	18	28
Total	913	55	281	17	84	5	78	5	319	19	1 672

Table 4.8

MONTHLY CATCH FOR THE DIFFERENT SECTORS

Date	Estimated catch per sector (t) and % of total										Total
	I		II		III		III A		III B		
	catch	%	catch	%	catch	%	catch	%	catch	%	(t)
February 1977	117.5	92	-	-	10.0	8	-	-	10.0	100	127.5
March	196.8	71	68.5	25	13.5	5	13.5	100	0		278.8
April	161.5	44	207.0	56	0.0	0	-	-	-	-	368.5
May	458.0	71	134.0	21	55.5	9	-	-	55.5	100	647.5
June	171.1	90	11.5	6	7.0	4	-	-	7.0	100	189.6
July	200.9	45	127.5	29	115.4	26	80.0	69	35.4	31	443.8
August	221.5	40	228.2	41	108.2	19	89.0	82	19.2	18	557.0
September	446.8	70	109.4	17	83.0	13	26.0	31	57.0	69	639.2
October	459.3	77	80.6	14	53.6	9	16.0	30	37.6	70	593.7
November	321.2	55	188.0	32	93.5	13	29.5	32	64.0	68	602.7
December	138.0	95	7.0	5	0.0	0	-	-	-	-	145.0
	2 892.6	63	1 161.7	25	539.7	11	254.0	47	285.7	53	4 594.0

Table 4.9

MONTHLY AVERAGE CATCH PER SET FOR THE THREE SECTORS

Date	Monthly No. of sets			Monthly estimated catch (t)			Monthly average catch per set (t)		
	I	II	III	I	II	III	I	II	III
November 1976	-	-	-	-	-	-	-	-	-
December	-	-	-	-	-	-	-	-	-
January 1977	1	-	-	0	-	-	0	-	-
February	40	1	4	117.5	0	10.0	2.9	0	2.5
March	50	12	8	196.8	68.5	13.5	3.9	5.7	1.7
April	49	28	0	161.5	207.0	-	3.3	7.4	-
May	85	20	7	458.0	134.0	55.5	5.4	6.7	7.9
June	47	11	4	171.1	111.5	7.0	3.6	1.0	1.8
July	87	56	51	200.9	127.5	115.4	2.3	2.3	2.3
August	84	75	32	221.5	228.2	108.2	2.6	3.0	3.4
September	200	36	22	446.8	109.4	83.0	2.2	3.0	3.8
October	161	11	20	459.3	80.6	53.6	2.9	7.3	2.7
November	87	30	11	321.2	188.0	93.5	3.7	6.3	8.5
December	22	1	0	138.0	7.0	-	6.3	7.0	-
Total	913	281	159	2 892.6	1 161.7	539.7	3.2	4.1	3.4

According to available records, 20 fish were taken from each sample to determine their maturity stage for which the following scale was used:

Maturity Stage	Stage No.
Immature	1
Mature unripe	2
Mature ripening	3
Mature near-ripe	4
Mature ripe (non-spawning)	5
Mature ripe (spawning)	6
Mature spent	7

For length distribution the total lengths of 50 fishes from each sample were measured to the nearest centimetre.

Probably from the same 20 fishes, used to determine the maturity stages, the stomach contents were recorded according to the following scale:

0 - empty

1 - a little

2 - almost full

3 - full

Also, from each sample the fat content (in percentage) was determined and recorded.

The author realized the limitations of the data, the bias in the sampling procedure and the need for a simple and generalized approach to the analyses and interpretation of the results. There is also some doubt about the sampling technique used after the departure of the fisheries biologist. Further, length, sex maturity and stomach contents of individuals examined did not appear in the records in sufficient detail and this reduced the precision of the analyses of biological information.

4.5.1 Species Composition

According to the distribution of the samples through the year the alternate predominance of the two species *S. longiceps* and *S. sindensis* can be distinguished (Tables 4.10). The stock of *S. longiceps* appeared to be most abundant in the area from March to the first fortnight of August, while *S. sindensis* dominated from the second fortnight of August to the first fortnight of November and possibly beyond that period.

Nearly all samples of *R. kanagurta* were collected in October while the samples of *M. auriflamma* were obtained in February-March, the beginning of the sampling period. Samples of *S. perforata* were scattered throughout the period.

4.5.2 Sardinella longiceps

From February up to the first few days of December 1977, 161 samples of *S. longiceps* were collected and analysed; 75% of the samples were taken in the period from March until the first fortnight of August 1977.

(i) Maturity

In the records the results of the analyses of samples for maturity were found grouped on a fortnightly and monthly basis and percentages calculated (Fig. 4.7). The maturation process has been described in the Company reports as follows for the 16/17 cm modal group.

"In the second fortnight of February we observed the first batch of ripe fishes and immediately afterwards this species started spawning. The first spent fish appeared in April and in the second fortnight of April already more than 50% of the fish were spent. In the first fortnight of May this percentage increased to 70%. The last ripe running individuals (spawning fish) were observed in June and afterwards the gonads were mostly in the resting stage. In the second fortnight of October the gonads started developing again and in the second fortnight of November mature ripe (non-spawning) specimens formed more thatn 40% of the samples. However, in the first fortnight of December this percentage declined to 20%." Whether this development resulted in a second short spawning period in December/January could not be confirmed.

(ii) Length distribution

The length frequency distributions of the samples were examined for fortnightly and monthly variations (Fig. 4.6). The length range was between 7 and 19 cm and the diagrams showed four different modes, as given below.

Modal length	Period
8 cm	July II - August
11-12 cm	September II - October - November I
13-14 cm	March II, May II - June I, August
16-17 cm	The whole period

Taking into consideration only one spawning season there is a possibility that the 8 cm and 11/12 cm modal groups may represent year class 0, 13/14 cm group may be year class I and 16/17 cm may include fishes of year class I and II, depending on the season.

(iii) Stomach content (Fig. 4.7)

Here also the records of the individual samples were grouped fortnightly and monthly.

Dùring the spawning season the percentage of specimens with "almost full" (2) and "full" stomachs (3) were more than 70%. However, this percentage decreased slowly in the gonad "resting" period and in September to October the specimens with "empty" or "little" in their stomachs formed more than 70% of the total. This percentage decreased rapidly and a feeding period starts during which the stomachs of all specimens are "full" or "almost full".

(iv) Fat content

The individual value for each sample has been totalled and a fortnightly and monthly average calculated (Fig. 4.7).

4.5.3 Sardinella sindensis

From February to November 1977, 139 samples have been collected and analysed; 71% of the samples were collected in the period between the second fortnight of August and November 1977.

(i) Maturity

As in the case of S. longiceps, the samples have been grouped and the percentages presented in a block-diagram (Fig. 4.9). The maturation process is described in the Company reports for the specimen with a modal length of 13/14 cm: "In the first fortnight of May 50% of the specimens were ripe (non-spawning). In the second fortnight of May a small percentage of the fish were spawning, in the second fortnight of June nearly 90% of the fish were ripe, and in the following months no "spawning" or "spent" specimen had been observed."

Table 4.10

MONTHLY (IN PARENTHESES) AND FORTNIGHTLY NUMBER OF SAMPLES TAKEN DURING THE FISHING OPERATIONS
RAS AL KHAIMAH, JANUARY-DECEMBER 1977

Species / Month	Fort-night	*Sardinella longiceps*	*Sardinella sindensis*	*Rastrelliger kanagurta*	*Sardinella perforata*	*Mulloidichthys auriflamma*	Others
January	I II	0 0 (0)	0 0 (0)	0	0	0	0
February	I II	3 4 (7)	5 4 (9)	0	0	3	5
March	I II	4 9 (13)	2 4 (6)	0	1	4	2
April	I II	11 6 (17)	2 3 (5)	0	1	0	3
May	I II	16 16 (32)	1 3 (4)	0	3	0	0
June	I II	2 10 (12)	4 1 (5)	0	0	0	0
July	I II	12 17 (29)	- 6 (6)	0	0	0	1
August	I II	18 8 (26)	5 13 (18)	0	0	0	1
September	I II	2 2 (4)	17 13 (30)	0	0	0	0
October	I II	2 3 (5)	21 13 (34)	10	1	0	0
November	I II	10 3 (13)	19 3 (22)	1	1	0	0
December	I II	3 - (3)	0 0 (0)	0	0	0	0
Total		161	139	11	7	7	12

These observations indicate that the main spawning area may possibly be outside the area fished by the vessels, which makes it difficult to determine the spawning period for S. sindensis.

In the second fortnight of July no specimen with maturity stage V had been recorded and probably the "resting period" of the gonads commenced. During December-February all specimens had been recorded as immature.

The above description of maturation process concerns the 13-14 cm modal group, the length of first reproduction for S. sindensis.

(ii) Length distributions

Fortnightly and monthly variations in the length frequency distributions were examined (Fig. 4.8). The length range is between 9 and 16 cm with the main mode at 13/14 cm while there is a suggestion of a second mode at 11/12 cm occurring in the September (II), October and November (I). It was noted that in that same period specimens with a length of 9 cm also had been recorded.

Since the spawning season could not be determined clearly, it is difficult to draw conclusions regarding age and growth.

(iii) Stomach contents

Here also the records showed that samples were grouped fortnightly and monthly (Fig. 4.9).

During the period March to July I the stomachs of the specimens were "almost full" to "full", while during August II - October II more than 40% of the specimens had little or nothing in their stomachs. Feeding starts again in the first fortnight of October and in the second fortnight of November all stomachs are "full" to "almost full".

(iv) Fat content

The individual values for each sample were totalled and fortnightly and monthly averages calculated (Fig. 4.9).

In March the fat content decreased reaching a minimum in May-June and it increased sharply in July to decrease very slowly until November except for a noticeable low level in September and early part of October. The recovery from the second half of October coincides with the increasing feeding activity.

4.5.4 Sardinella perforata

The seven samples were grouped monthly and length frequency distributions were made (Fig. 4.10). They were observed to be unimodal with the modal length for March and May around 14 cm while that in October-November was around 10 cm. As 65% of the specimens were "mature" and 36% were "mature ripe" (non-spawning) in May, the species must have been near its spawning season or in its spawning season. In October/November the gonads were immature. However, the analysed samples were taken from another length group.

In March and May the stomachs were "almost full" to "full" while in October 50% of the analysed specimens had little in their stomachs.

In March the fat content was 5.2% which dropped in May to 2.1%. In October/November it was 2.0%. Based on the maturation process, stomach content and fat content data, it seems highly probable that S. perforata has a similar biological life cycle to S. sindensis. However, like S. sindensis the spawning area is probably outside the fishing area and taking into consideration the relative proportion of the amount of samples, the main stock of S. perforata may also be outside the area fished by the vessels.

4.5.5 Dussumieria sp.

Only one sample (No. 35) was taken in February and gonads were "mature", "ripening", "near ripe"; stomachs "almost full" to "full" and fat content 4%.

4.5.6 Comparison of the Biology of the four Clupeidae Species

According to the results of the analysis the biology of the three Sardinella species, S. longiceps, S. sindensis, S. perforata, seem rather similar but with a difference in spawning areas. S. longiceps has its spawning location at least for one length group in the fishing area, while both other species seem to spawn outside the fishing area. Most probably the optimum habitat for S. perforata is also outside the fishing area.

For all the three species only one spawning period could be determined. However, for S. longiceps there are indications that a second minor spawning might occur in winter.

In spite of the poor information on the species Dussumieria sp. it seems at least that its spawning season starts together with the one of the Sardinella species.

4.5.7 Rastrelliger kanagurta

In October 1977, 11 samples of R. kanagurta were analysed. The results have been grouped on a fortnightly and monthly basis and are illustrated in Fig. 4.10.

The diagrams are unimodal with a changing mode from 16 cm in the first fortnight to 17 cm in the second fortnight of October. All specimens analysed were immature and approximately 80% of them had an "almost full" to "full" stomach while no empty stomachs were observed.

The fat content varied from 3.2% in the first fortnight to 3.8% in the second fortnight and was average 3.5% for the total analysed samples.

4.5.8 Other Species

Seven samples of Mulloidichthys fulviflamma were taken in February and March and the different distributions were grouped monthly (Fig. 4.10). The diagrams showed a mode at 11-12 cm. The gonads were immature and the stomachs in almost all cases were "almost full". The average fat content was 4.8%.

Two samples of Decapterus russelli were analysed in April (No. 63). Modes at 10 and 16 cm. Modes at 10 and 16 cm, gonads "immature" to "mature unripe" and stomach content "almost full" to "full". Fat content was 1.8%.

One sample of Caranx leptolepis was analysed in February (No. 74), mode at 10 cm, gonads immature, stomach "almost full" and fat content 1.0%.

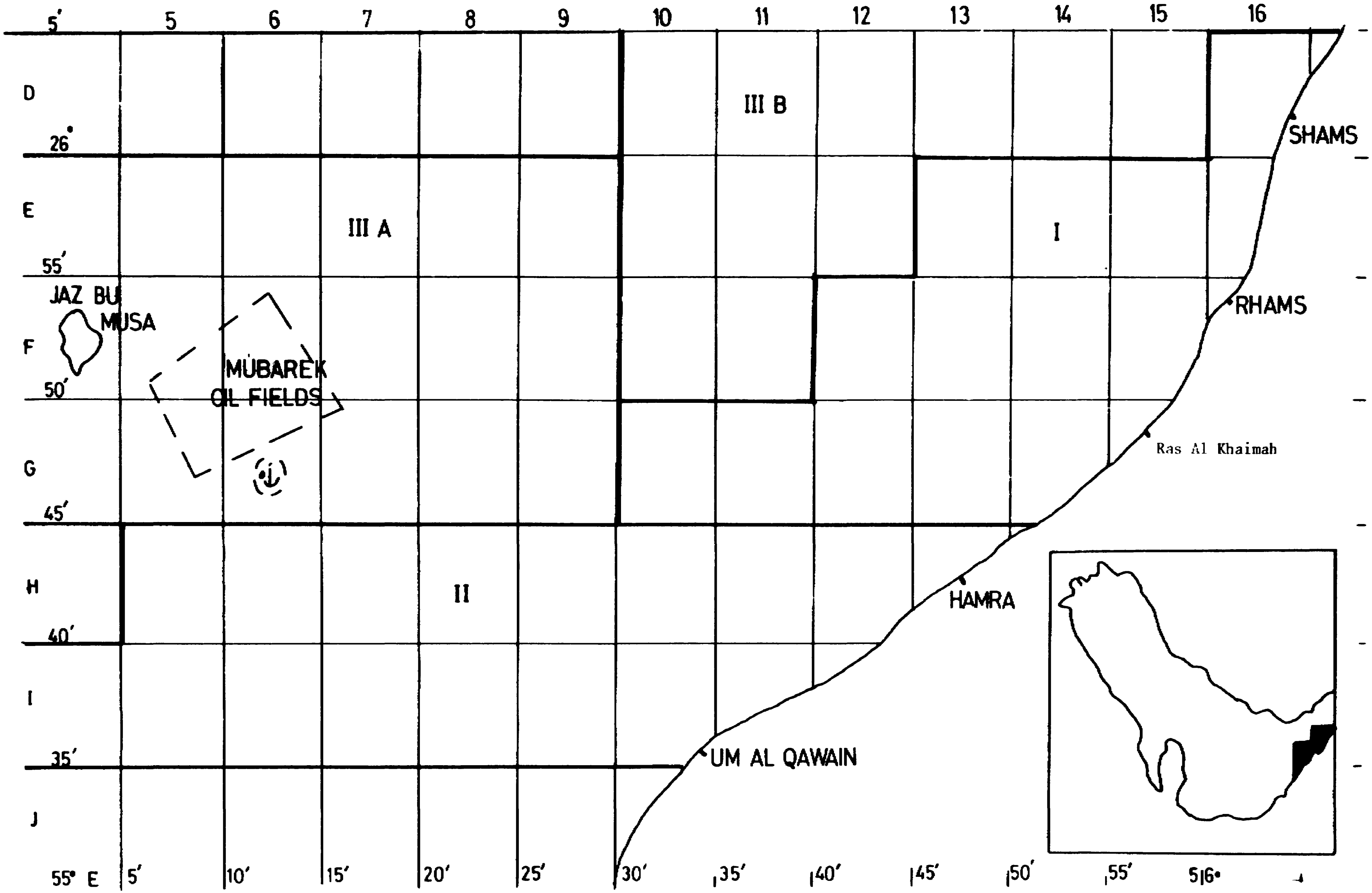
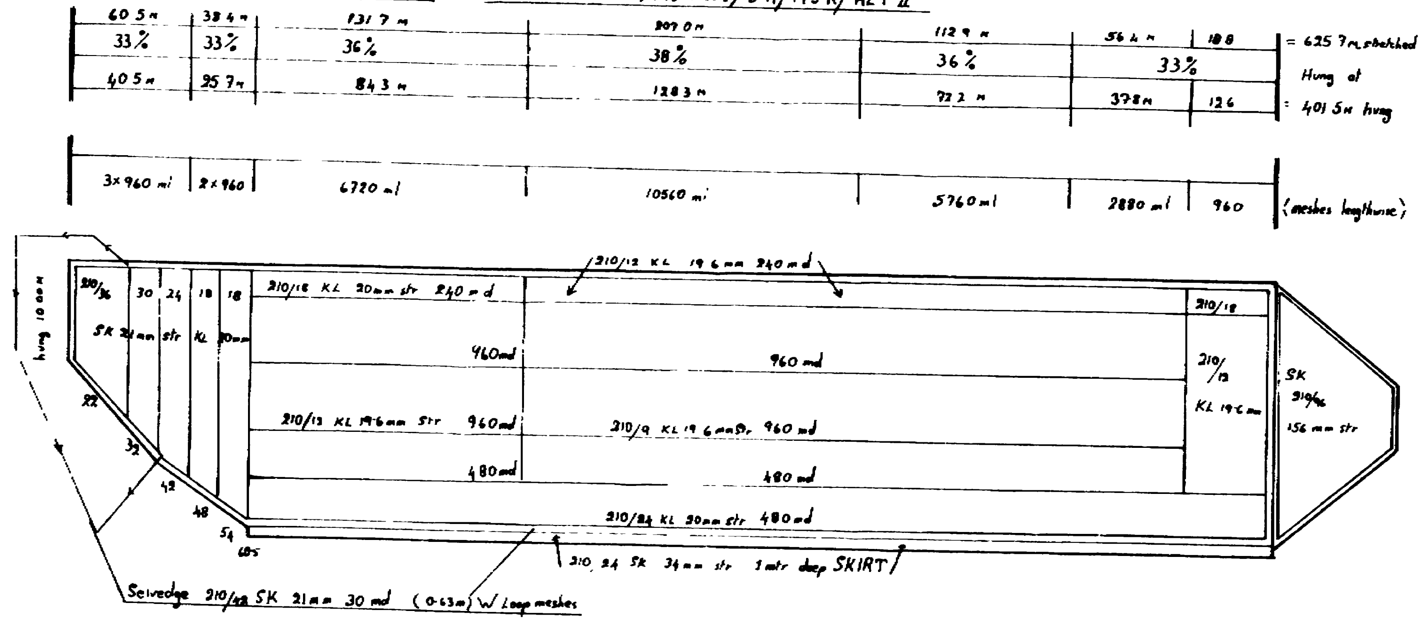


Fig. 4.1 Fishing area with the four sectors (I, II, III A, III B) and grid system used by Ras Al Khaimah Fishing Company

Fig. 4.2 Type: Purse Seine for Middle-East Waters   Ref UAE/2-75/FID-NOFI/JA/MJR/ALT II



Hung length along corkline – 401 5 metres
Hung length along leadline – 401 5 " "
Stretched length – 625 7 " "
Stretched depth – 60 5 metres

Meshsize in bunt – 21 mm - 20 mm
Meshsize in body – 20 mm - 19 6 mm - 40 mm
Meshsize in choke – 156 mm all stretched

Float rope – 14 mm dia Multiflex (PP)
Corkline rope – 2x16 mm dia Terylene (PES)
Leadline rope – 2x16 mm dia Terylene (PES)
Bridles – 12 mm dia Polypropylene (PP)
Sinkers – 725 kgs
Floats – 1205 pcs 6" x 7-1/2 (6272)
Purserings – 41 pcs each 3 kgs
Breastrings – 40 pcs each 0 5 kgs

Ropes and Netting - Dyed black and treated

SK - single knot KL - knotless

Drawing not to scale

NORSENET LTD. PO Box 646
BERGEN NORWAY

Nov 1975

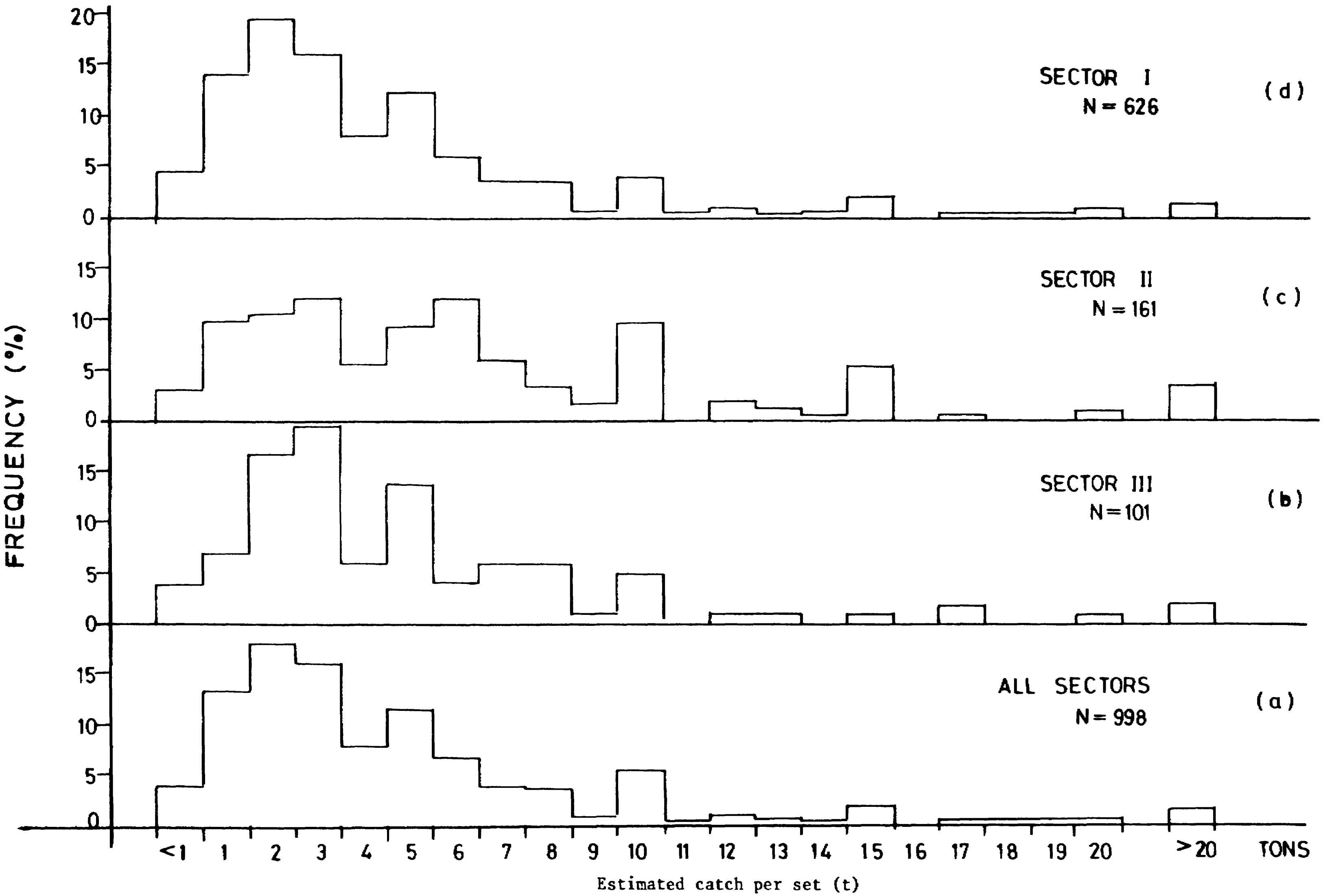


Fig. 4.3 Frequency distribution of estimated catch per set per sector of the fishing area, Ras Al Khaimah, November 1976 - December 1977

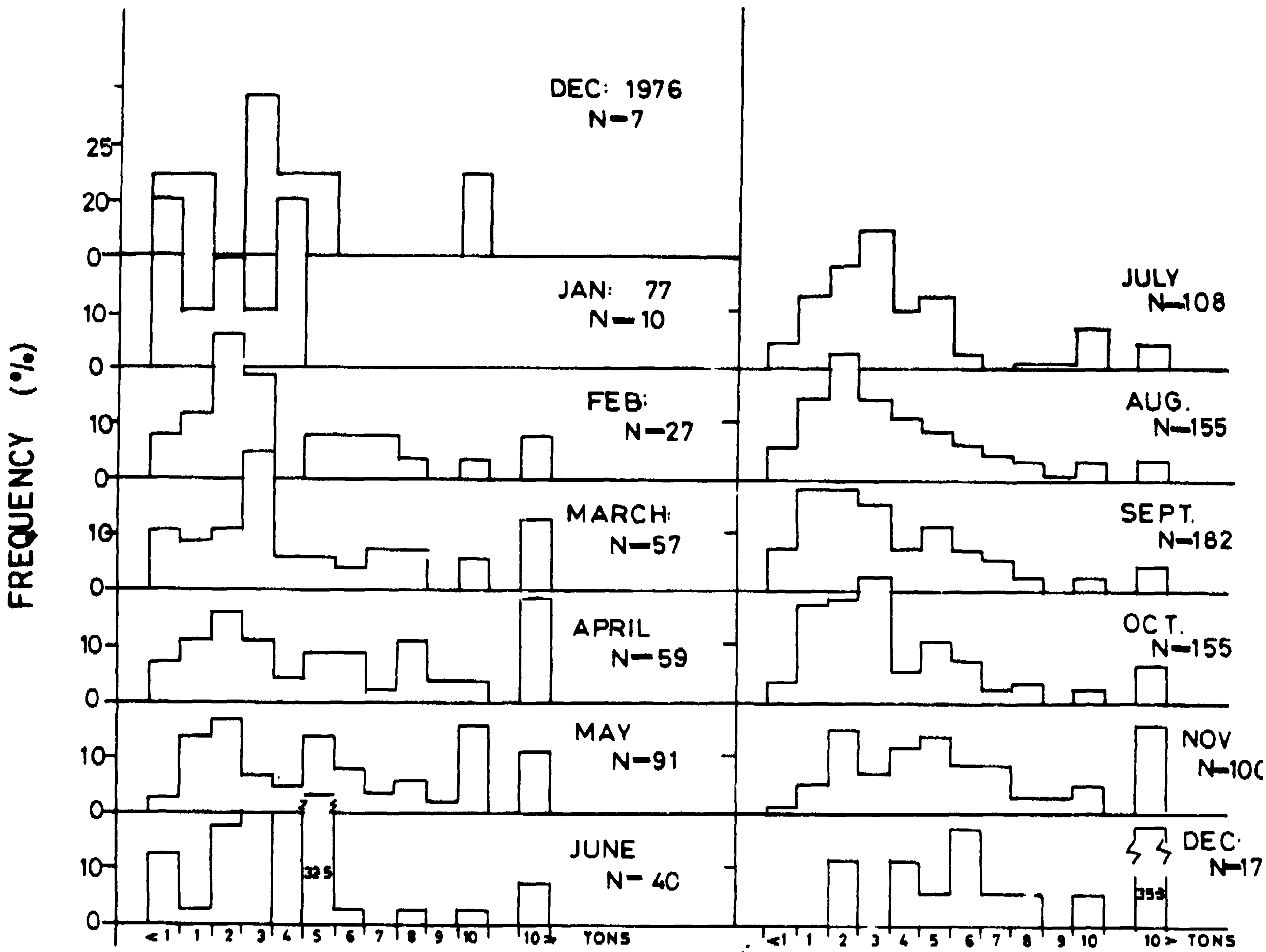


Fig. 4.4 Frequency distribution of catch/set by season, Ras Al Khaimah, December 1976 - December 1977

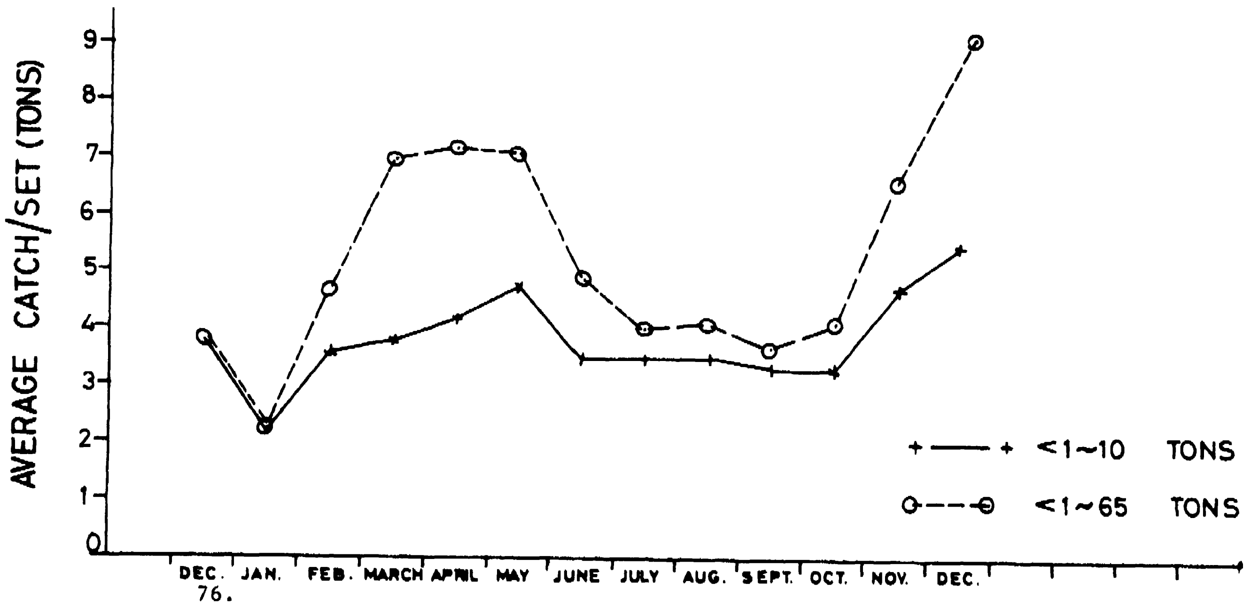


Fig. 4.5 Seasonal variation in the catch per set

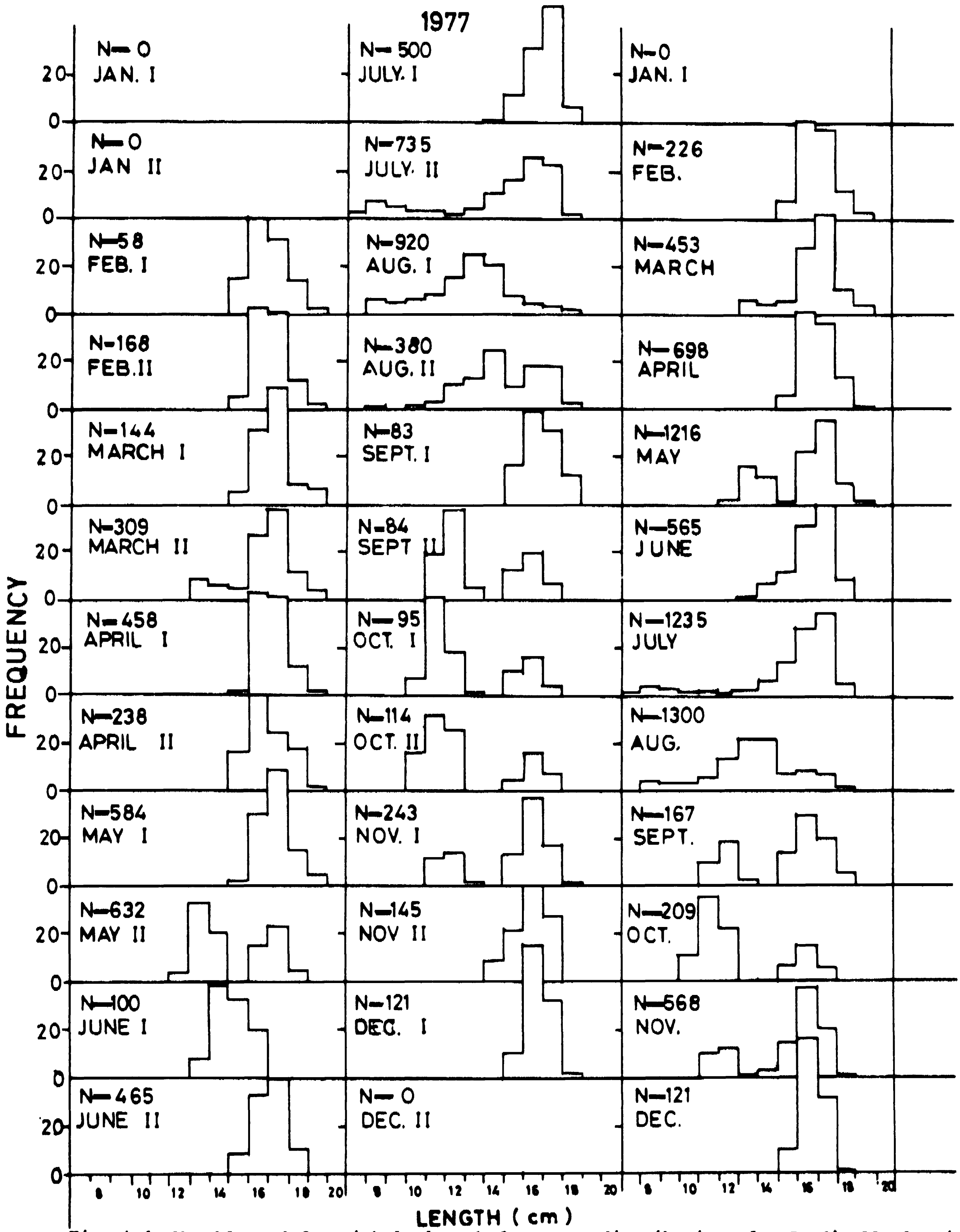


Fig. 4.6 Monthly and fortnightly length frequency distributions for Sardinella longiceps, Ras Al Khaimah, 1977

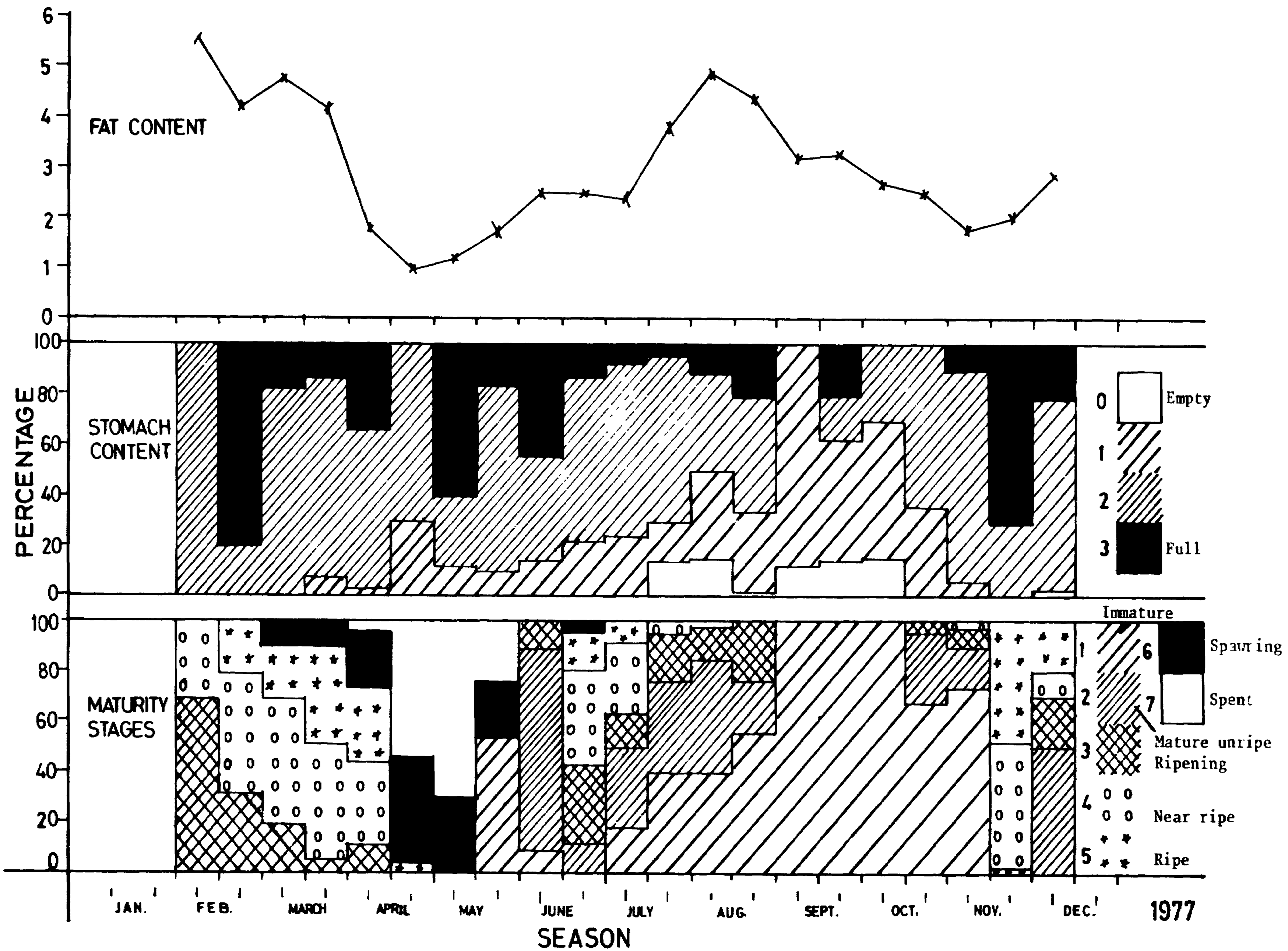


Fig. 4.7 Seasonal variations in maturity, stomach contents and fat contents of <u>Sardinella longiceps</u>, Ras Al Khaimah, 1977

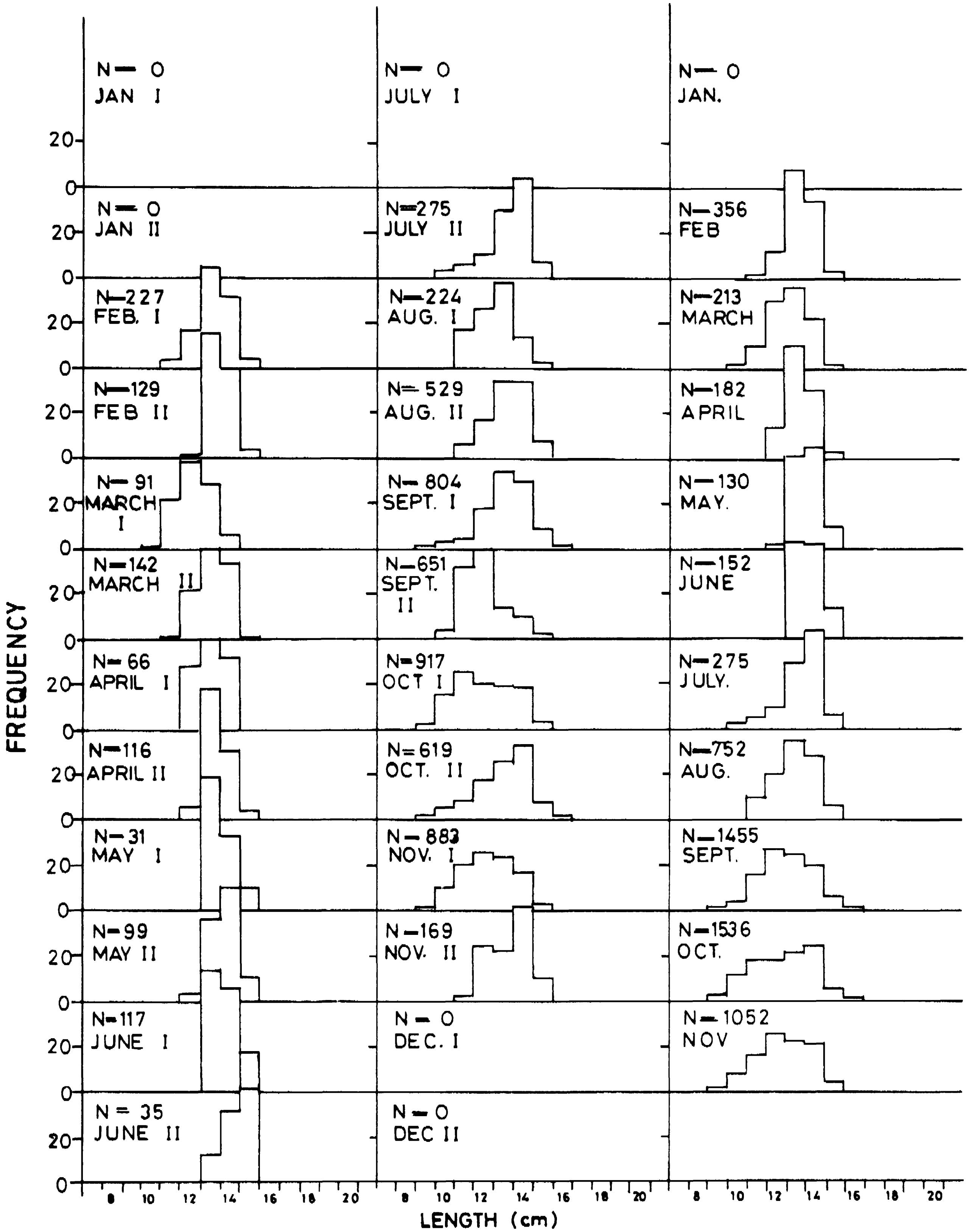


Fig. 4.8 Monthly and fortnightly length frequency distributions for Sardinella sindensis, Ras Al Khaimah, 1977

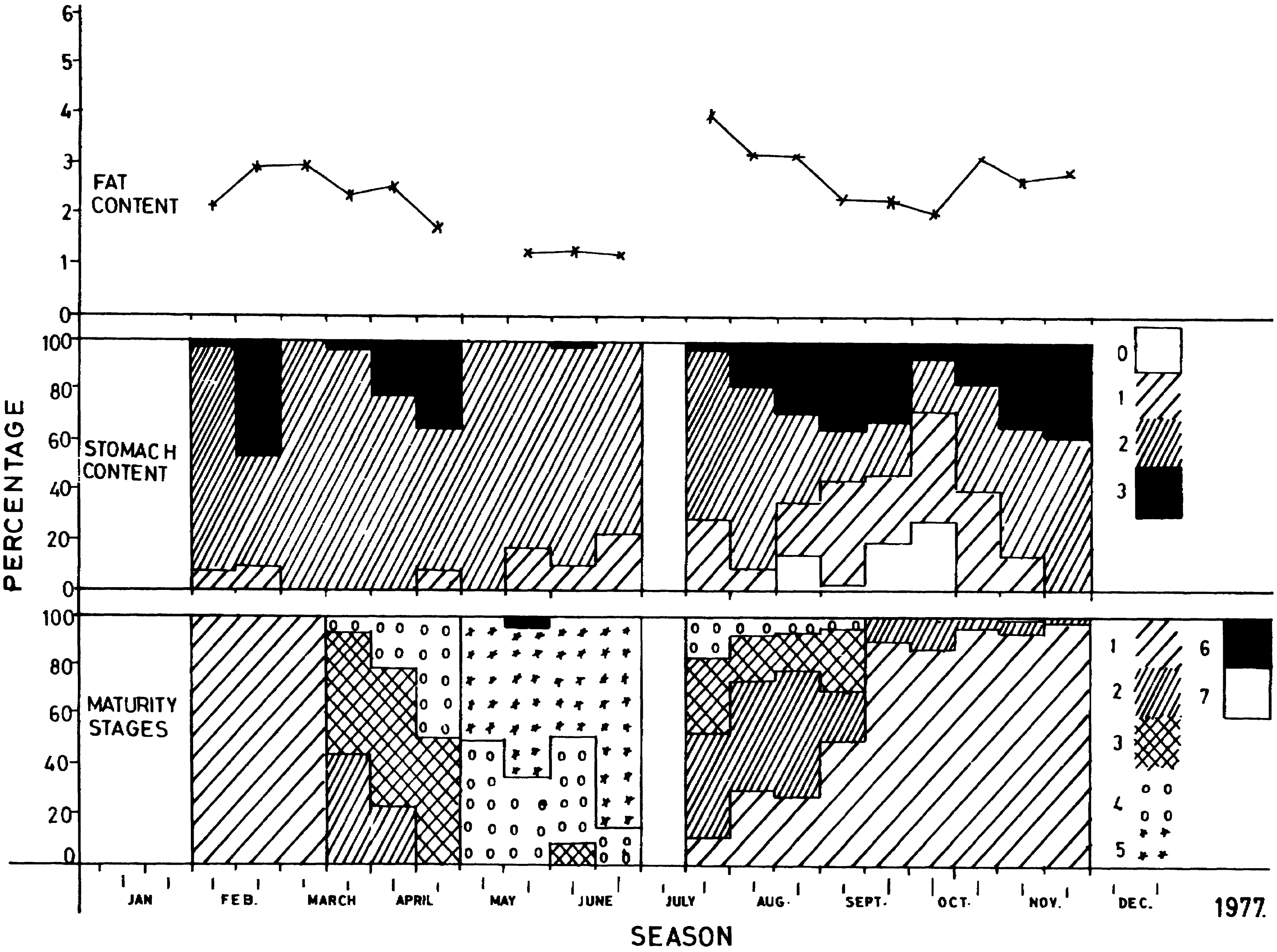


Fig. 4.9 Seasonal variations in maturity, stomach contents and fat contents of Sardinella sindensis, Ras Al Khaimah, 1977

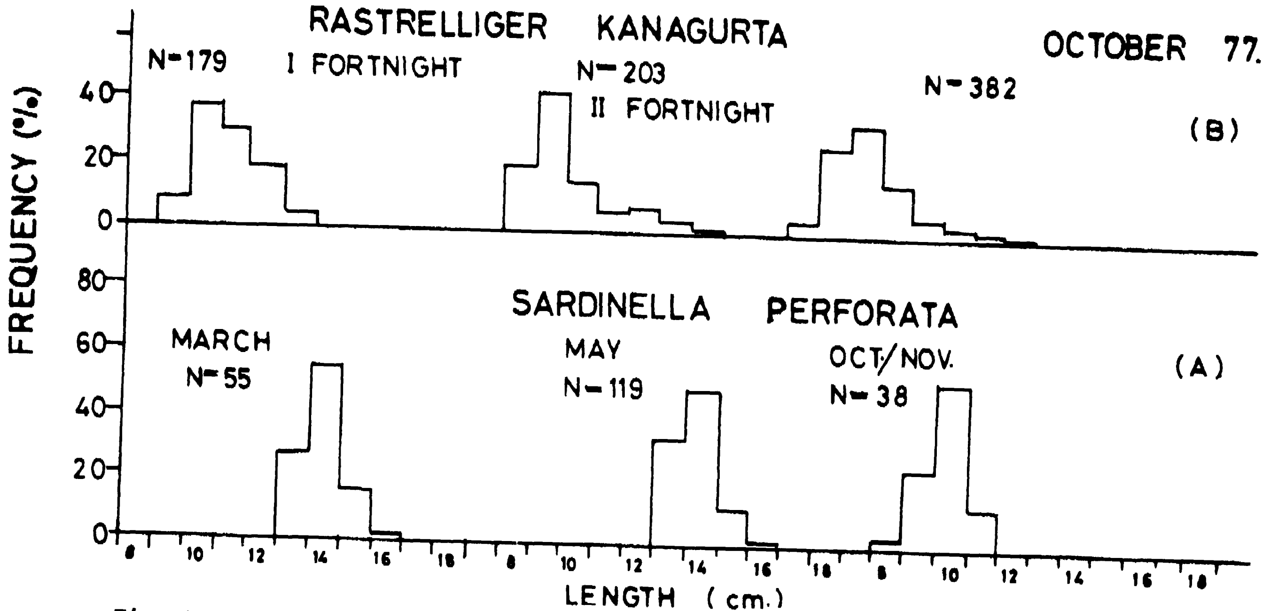


Fig. 4.10 Length frequency distributions for Sardinella perforata and Rastrelliger kanagurta, Ras Al Khaimah, 1977

5. LARGE PELAGICS IN THE GULF AND GULF OF OMAN

by

K. Sivasubramaniam

5.1 INTRODUCTION

The present level of exploitation of the resources of large pelagic species in the project area is estimated to be approximately 21 000 t/yr. The contribution by each country to this level of production varies significantly, and nearly 70 percent is contributed by Oman and Iran.

In view of the generally high commercial value of large pelagic fish, it was decided that the R/V MAJID should make observations and catches of this group while carrying out the main programme of exploratory purse seining for small pelagics. However, these observations could not be made over the entire project area or cover all seasons. Therefore, the results of MAJID's cruises made between August 1977 and August 1978, have been considered together with additional information available from other sources.

5.2 METHODS OF INVESTIGATION

During her exploratory cruises for small pelagics, MAJID also operated three single-hook trolling lines while sightings of schools of large pelagics were recorded. Data on duration of trolling, area, number of schools sighted, identification of species, etc., were logged. Sometimes attempts were also made to encircle tuna schools with the sardine purse seine net.

Catches made by trolling and purse seining were sampled for species identification, length frequency distribution, length-weight relationship, sex ratio, maturity and stomach contents. As most of the cruises were on the east and west coasts of UAE and the Strait of Hormuz, the results pertain mainly to these areas and not to the whole project area.

Observations made on the artisanal fishery landings in many of the member countries helped to identify general distribution and production trends, both by area and season. Though the demersal trawl is not a suitable gear for sampling such pelagic species, data on the catches of these species made during the trawl survey was also analysed for extraction of information on their distribution in the project area. Reports on the existing fishery and exploratory fishing conducted earlier in the project area were also valuable for interpreting the results obtained and confirming the conclusions.

5.3 SPECIES AND THEIR GENERAL DISTRIBUTION IN THE PROJECT AREA

Results of the trolling line catches, incidental catches during the trawl survey, and observations on the landings of the artisanal fishery in various member countries showed the presence of *Scomberomorus commerson* (narrow barred king mackerel), *Thunnus tonggol* (longtail tuna) and *Euthynnus affinis* (eastern little tuna) as the predominant large pelagic species. However, *Scomberomorus guttatus* (Indo-pacific king mackerel), *Auxis thazard* (frigate tuna), *Scomberoides* spp. (queenfish), *Caranx* spp. (jacks), *Coryphaena hippurus* (common dolphinfish), *Sphyraena* spp. (barracudas) and Mugilidae (grey mullets) also were relatively important members of the large pelagics group in the project area. Species such as *Acanthocybium solandri*

(wahoo), Katsuwonus pelamis (skipjack), Thunnus albacares (yellowfin tuna), Sarda orientalis (oriental bonito), Chanos chanos (milkfish), Istiophorus orientalis (sailfish), Makaira sp. (marlin), Xiphias sp. (swordfish) and carangids such as Elagatis bipinnulata (rainbow runner) and Megalaspis cordyla (hardtailed scads) are known to occur but there is no clear indication of their abundance. Elasmobranchs such as Sphyrna mokarran (hammerhead), Carcharhinus brevipinna (spinner shark), C. melanopterus (blacktip shark), C. plumbeus (sandbar shark), C. sealei (blackspot shark), Galeocerdo cuvieri (tiger shark) and Mobula sp. (manta ray) were also identified.

As far as the general distribution of the major species of large pelagics is concerned, the narrow barred king mackerel was found to be the most widely distributed species, as it occurs in almost the entire project area. The longtail tuna is distributed more in the Gulf of Oman than in the Gulf where its distribution is restricted to the southeastern part, close to the Strait of Hormuz. Its occurrence is extremely rare in the northwestern part of the Gulf.

Eastern little tuna also shows a reasonably wide occurrence but appears to be distributed more on the southeastern part of the Gulf including the Strait of Hormuz than in other areas.

Indo-Pacific king mackerel has been observed mostly along the Iranian side of the Gulf.

5.3.1 School Sighting

An analysis of the records of schools sighted during MAJID's cruises, between August 1977 and May 1978, was attempted but due to lack of continuity, comparable seasons and reasonable equal scouting time could not be achieved for all three statistical areas (see Fig. 1.1). Scouting took place in Area 3 - August to October 1977 and May 1978; in Area 2 - September to November 1977 and January, February, April and May 1978; and in Area 1 - March and May 1978. The data, irrespective of season, showed that the number of schools of tuna and tuna-like fishes sighted per day in the western part of the Gulf of Oman varied from 0 to 18, and the frequency of occurrence of scattered tuna or tuna-like fishes varied from 0 to 25, giving an average of respectively 2 and 8 sightings per day of regular schools and scattered fish. In the southeastern part of the Gulf the number of schools of tuna or tuna-like fish sighted varied from 0 to 18, with an average of 9 schools per day. However, the frequency of occurrence of scattered tuna or tuna-like fishes was relatively less in this area, with a range of 0 to 4 sightings per day and an average of 1 sighting per day. During two cruises in the northwestern part of the Gulf (Area 1) MAJID recorded 0 to 29 sightings per day in March 1978 with an average of 2 schools sighted per day.

5.3.2 Results from Demersal Trawl Survey

The larger Scombridae formed only 0.8 percent of the catches with the bottom trawls as can be expected since this gear is not adequate for catching these species. The results, though poor, were examined for species distribution in the project area (see report on demersal species in the Gulf and Gulf of Oman, FAO, in press). The catch rates per stratum ranged from 0 to 26 kg/h but catches over 10 kg/h occurred along the entire Iranian coast in the Gulf, and in the substrata directly west and northeast of Qatar. Catch rates slightly less than 10 kg/h were observed in the area directly north of Bahrain. None of the substrata in the Gulf of Oman yielded comparable results. The 25-50 m depth stratum showed relatively higher concentrations both on the Iranian and Arabian sides of the Gulf, and the central part of the Gulf (50-100 m) exhibited relatively low densities. According

to the species composition of the trawl catches, Scomberomorus guttatus (Indo-Pacific king mackerel) was the main Scomberomorus species in the 25-50 m stratum all along the Iranian coast as well as in the shallow stratum (10-25 m) close to the Shatt al Arab, whereas S. commerson (narrow barred king mackerel) was predominant in the 25-50 m stratum on the Arabian side of Area 2 and all strata in Area 3 (Gulf of Oman). Bearing in mind that this group is not vulnerable to bottom trawl gear, a biomass of 9 000 t was estimated for the small component of the stock which was vulnerable to the bottom trawl gear used.

A few of the larger carangids listed above were also occasionally caught in the high opening bottom trawl.

5.3.3 Trolling Line Catches

Results of the catches made with the three single hook trolling lines fished by R/V MAJID are presented in Fig. 5.1. It was observed that longtail tuna is concentrated mainly in the Gulf of Oman and the Strait of Hormuz with relatively low frequency of occurrence inside the Gulf. In the Gulf, the troll catches were mainly eastern little tuna. There were indications of increasing catch rate of little tuna in the westerly and south-westerly directions from the Strait of Hormuz after August until November. The longtail tuna appeared in the catches east of UAE and the Strait of Hormuz from August, and along the west coast of UAE from September to November. Few schools of longtail tuna were seen in the middle part of the southeastern half of the Gulf, in March. However, the little tuna seemed to be more abundant than longtail tuna inside the Gulf.

Trolling for 58 h between January and May, 40 h between June and August and 129 h between September and December give average catch rates of 1.4 kg/h, 0.9 kg/h and 2.2 kg/h respectively. A decline from the first half of the cool period to the very warm period was evident.

Sighting of schools of little tuna in the northwestern part of the Gulf in March/April and the decline of the troll catch rates in the southeastern part of the Gulf in January/February could perhaps mean that this species, after concentrating in the eastern part of the Gulf between September and November/December, spreads westwards into the northwestern part of the Gulf from January until April/May at the beginning of the warm season.

5.3.4 Purse Seine Catches

While conducting exploratory fishing with a purse seine net for small pelagics occasional attempts were made to catch large pelagics with the same gear. Because of the unsuitability of this gear for large pelagics four specific attempts to catch tuna schools were unsuccessful. However, on six other occasions, while attempting to encircle sardines or anchovy, little tuna were caught, viz., in Area 2, close to UAE and Iran coasts in April and October. The catches of little tuna in October were negligible (3-20 kg/set), whereas in April there was a catch of 222 kg close to the Iran coast.

5.4 CATCH INFORMATION FROM OTHER SOURCES

5.4.1 The Ras Al Khaimah Fishing Company vessels normally purse seining for sardines also attempted to catch tuna and the results of their attempts are presented in Fig. 5.2 and Table 5.1. The results indicated the highest occurrence of tuna schools on the west coast of UAE during the cooler months of the year. In fact 12 367 pieces of tuna were landed in

December by the Company vessels, but unfortunately details of the number of sets for this month were not available and hence the entries made in Table 5.1 for December are incomplete. The poor results in November may have been because of the good sardine catches during that period, and the boats may have concentrated their effort on sardines rather than on tunas (see part 4). In fact the sardine catches were relatively good between February and May, and therefore the tuna catches during this period could also have been affected in the same way as in November. July and August have been lean months for both large pelagics and small pelagics. The occurrence of sailfish and spearfish in the area was not evident from the artisanal fishery landings.

Table 5.1

LARGE PELAGICS CAUGHT BY RAS AL KHAIMAH FISHING COMPANY PURSE SEINERS IN 1977

Season	Fishing ground (grid number in Fig. 5.2)	Number of sets	Catch in tons or pieces	Main species
February	G 16	1	6	Tuna, sailfish
	E 15	1	0	
	G 13	1	0	
March	D 16	1	50 pieces	Tuna
April	D 16	1	0	
	H 6	1	1 t + 12 pieces	12 pieces sailfish
July	G 7	1	0	
	D 16	1	300 pieces	?
August	D 16	2	4 pieces	4 pieces sailfish and few tuna
October	F 13	1	3 t	1 t sailfish
	H 10	1	1.6 t	
	D 15	1	1.6 t	
November	H 11	1	0	
December 1/	F 13	1	300 pieces	Weight unknown
	G 10	1	1.7 t	Sailfish with 4.3 t sardine
	G 14	7	5 t + 2 186 pieces	?
	G 13	2	3 t	Tuna
	G 15	2	4 t	Tuna

1/ Records for this month were incomplete

5.4.2 R/V MAJID Exploratory Fishing in 1970/71: White and Barwani (1976) reported that many schools of tuna were sighted in the southeastern part of the Gulf between September and December 1970, and a lesser number of schools during April-June 1970. In the Gulf of Oman schools of large pelagics were sighted from May through December 1970 and April through

June 1971. Purse-seining results in the southeastern part of the Gulf were discouraging in respect of tunas, against 8.4 t/set for sardines. Attempts in the Gulf of Oman produced slightly better results for tuna (0.45 t/set), good results for large carangids (5.1 t/set) while results for sardines were relatively poor (1.6 t/set) compared with the Gulf. During these cruises yellowfin tuna (Thunnus albacares) had been identified as the major tuna species, while there was no record of catches of longtail tuna. On the contrary, during the present survey longtail tuna has been identified as the major tuna species and yellowfin has been rarely observed in the project area.

Table 5.2

ESTIMATED AVERAGE ANNUAL PRODUCTION OF LARGE PELAGICS (1976-1978) IN THE PROJECT AREA AND THE MAIN SPECIES CONTRIBUTING

Country	Estimated annual production (t)	Percentage of the total production	Main species in the order of predominance
Iran 1/	6 000	17	S. guttatus, T. tonggol, E. affinis, S. commerson, Carangids
Iraq	100	10	S. guttatus, Mugilidae, etc.
Kuwait	500	6.6	S. guttatus, Mugilidae, Carangids, etc.
Saudi Arabia	1 C00	15	S. commerson, Carangids, etc.
Bahrain	700	14	S. commerson, Carangids, E. affinis
Qatar	500	19	S. commerson, Carangids, E. affinis
UAE	3 200	33	S. commerson, T. tonggol, Carangids
Oman (north coast)	9 000	43	S. commerson, T. tongool. E. affinis, Carangids, etc.
Total	21 000	23	S. commerson, T. tonggol, S. guttatus, E. affinis, Carangids

1/ Includes results of large-scale fishery for large pelagics

Source: FAO, in press

5.4.3 Artisanal Fishery Landings

Based on the information collected on the landings by the artisanal fishery in the project area, an estimate of the present level of annual production of large pelagics is about 21 000 t or 23 percent of the total production of the Gulf.

The monthly variations in the production of major groups showed that king mackerels, longtail tuna and little tuna are similar in their seasonal variation of availability within the project area. On the northern coast of Oman, this group contributes to the production almost all the year round. Sampling of the landings in Muscat over a six-month period showed that large pelagics formed nearly 84 percent of the landings in June, 68 percent in July and only 40 percent in August to November. S. commerson significantly influenced the seasonal variation in the production of large pelagics together with dolphinfish. The main season appeared to be between June and November with August as the peak month (FAO, in press). In the Strait of Hormuz the best season is between October and May (Fibiger and Frederikson, 1957), and inside the Gulf the main season is between November and March/April with the peak around January (FAO, in press; Hull, 1978; and Abbes and Ferrugio, 1977). Longtail tuna does not appear in the landings of any country west of Qatar, and little tuna is insignificantly represented in the landings. In the northwestern part of the Gulf king mackerel constitutes the main large pelagic species except in the Shatt Al Arab area where Mugilidae (mullets) also make a very significant contribution (approximately 30 percent) to the production of pelagics (FAO, in press).

On the Iranian side of the Gulf, catches of king mackerel improve with the onset of the cool season. This species moves westwards and is caught near Bandar Langeh until April. This migration is suspected to be influenced by the spreading of cool and low saline water through the Strait of Hormuz into the Gulf. With the warming-up of the Gulf waters in summer, the king mackerel appears to move back into the Strait of Hormuz. It is caught near Bandar Abbas until June and is then found close to Mubarak in July (Abbes and Ferrugio, 1977).

5.5 BIOLOGICAL INFORMATION

5.5.1 Size Composition

Scomberomorus commerson caught during the trawl survey in the southeastern part of the Gulf were less than 20 cm in length (fork length) in July, 30-40 cm in September and 40-98 cm in November. On the west coast of Qatar the size composition resembled that of the eastern side during November (Fig. 5.3). Scomberomorus guttatus, frequently observed along the Iranian coast in the Gulf, was between 20 and 50 cm and the mode showed a shift from 28 and 30 cm to 40-42 cm between October 1977 and June 1978 (Fig. 5.4).

The fork length of E. affinis caught in the project area ranged from 27-69 cm. In the southeastern part of the Gulf, where they are mainly found, the size composition exhibited a predominance of smaller size range of 25-45 cm at the tail end in the third quarter and the fourth quarter of 1977, to 35-45 cm range during the first quarter of 1978 and 45-65 cm range at the beginning of the second quarter of 1978 (Fig. 5.5). Though samples of 50-70 cm size range also were caught throughout the above-mentioned periods, they emerged as a dominant size group only in April 1978. Considering the age-size relationship suggested for E. affinis in the Indian Ocean by Wheeler and Ommanny (1953), the length composition observed would probably be that of advanced second-year and third-year groups. In the Gulf of Oman juveniles of this species appeared in artisanal fishery landings in October.

In the case of T. tonggol, the size range observed was 30-60 cm with one individual measuring 66 cm (Fig. 5.6). The samples were insufficient to bring out any clear trends. However, it is worth noting that on the western side of the Indian Ocean this species has been

recorded as entering the surface fishery between the Gulf of Aden and the Gulf of Oman. The size range reported was 58-65 cm with an average length of 60.8 cm (2-4 kg), from purse seine catches in the Gulf of Aden (Ben Yami, 1975). In the Arabian Sea, off the west coast of India, this species appears in tuna longline catches, and in April 1966 the size composition was reported as 63-70 cm with the mode at 63-66 cm (Kawaguchi, 1967).

5.5.2 Sex Ratio and Maturity

About 180 individuals of *Euthynnus affinis*, 175 of *Scomberomorus guttatus*, 28 of *S. commerson* and 70 of *Thunnus tonggol* were examined for sex and gonad maturity. In the case of *E. affinis*, the sex ratio of male to females was 1:1.6, for *T. tonggol* it was 1:1.2 and for *S. guttatus* it was 1:1. Any variation according to season, size and area could not be attempted due to insufficient number of samples. Examination of the gonads for maturity of the samples collected in the project area indicated that *E. affinis* of 35-40 cm length range, *T. tonggol* of 45-50 cm size and *S. guttatus* of 35-40 cm were mature fish. In the Gulf, 6% of *E. affinis* samples examined in April had ripe ovaries. No ripe ovary was observed among the samples of this species from the Gulf of Oman. Only one specimen in the samples from the Gulf of Oman in March of *T. tonggol* exhibited a ripe ovary, but, 80% of the samples taken in August were fully mature.

In the case of *S. guttatus* the percentage of females with ripe ovaries was 10 in March, 32 in April and 53 in June while 37% in the samples of April and 45% of those of June had spent ovaries. Investigations carried out by the Saudi Arabian Fisheries Development Project showed that *S. commerson* spawn around April/May (verbal communication).

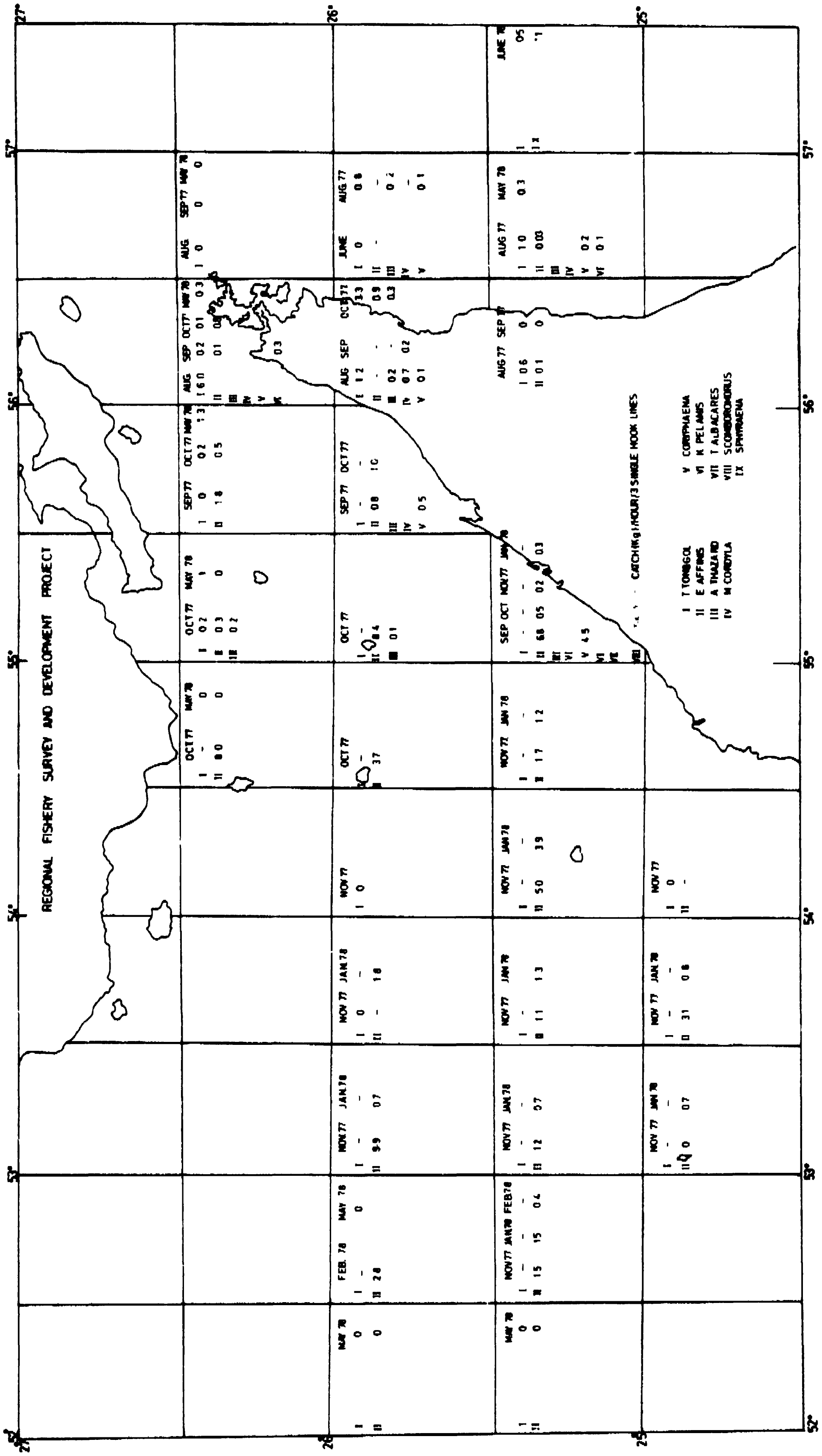
5.6 CONCLUSION

The investigations carried out on the large pelagics in the project area were not in the form of a systematic survey. The observations and incidental troll line catches made by R/V MAJID and the scanty information available on existing fisheries for this group, provide a meagre input to our knowledge on the species composition of large pelagics, their distribution patterns, seasonal variation and level of production. With this little information it is not possible to make a reasonable assessment of the status of the stocks.

At present, the production of this group is mainly through artisanal fishery using large mesh size gillnets or driftnets, except in Iran where a small fleet of vessels are engaged in a large-scale fishery.

Fishing technologists (consultants to the project) have commented on the efficiency of the gear used in the area for large pelagics and have recommended improvements to the fishing gear (Davidson Thomas, in press and Kristjonsson, in press). Further, it is not clear how much effort is being specifically directed to this resource, except that there is a noticeable increase in effort when catches of other, more valuable species, become poor and some effort is shifted to the fishery for large pelagics.

In light of the above, it is conjectured that improvement of existing gear for large pelagics, increase in effort not only by increasing the number of crafts but also in the quantity of gear used per craft, combined with a better understanding of the behavioural patterns of the species, could lead to an increase in production to almost double the present level of estimated production.


REGIONAL FISHERY SURVEY AND DEVELOPMENT PROJECT
CATCH (Kg)/HOUR/3 SINGLE HOOK LINES
I T TONGGOL
II E AFFINIS
III A THAZARD
IV M CORDYLA
V CORYPHAENA
VI K PELAMIS
VII T ALBACARES
VIII SCOMBEROMORUS
IX SPHYRAENA

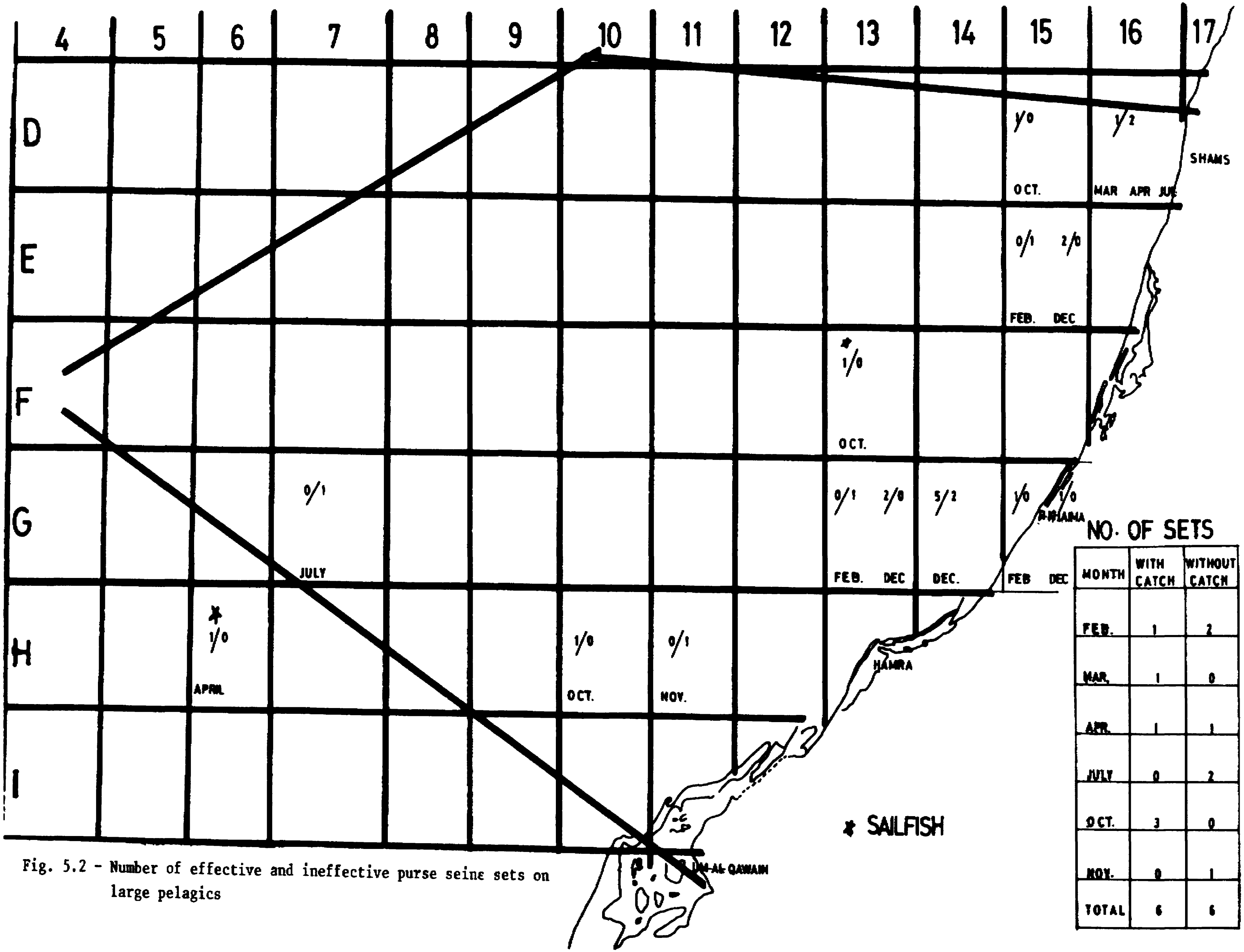


Fig. 5.2 - Number of effective and ineffective purse seine sets on large pelagics

NO. OF SETS

MONTH	WITH CATCH	WITHOUT CATCH
FEB.	1	2
MAR.	1	0
APR.	1	1
JULY	0	2
OCT.	3	0
NOV.	0	1
TOTAL	6	6

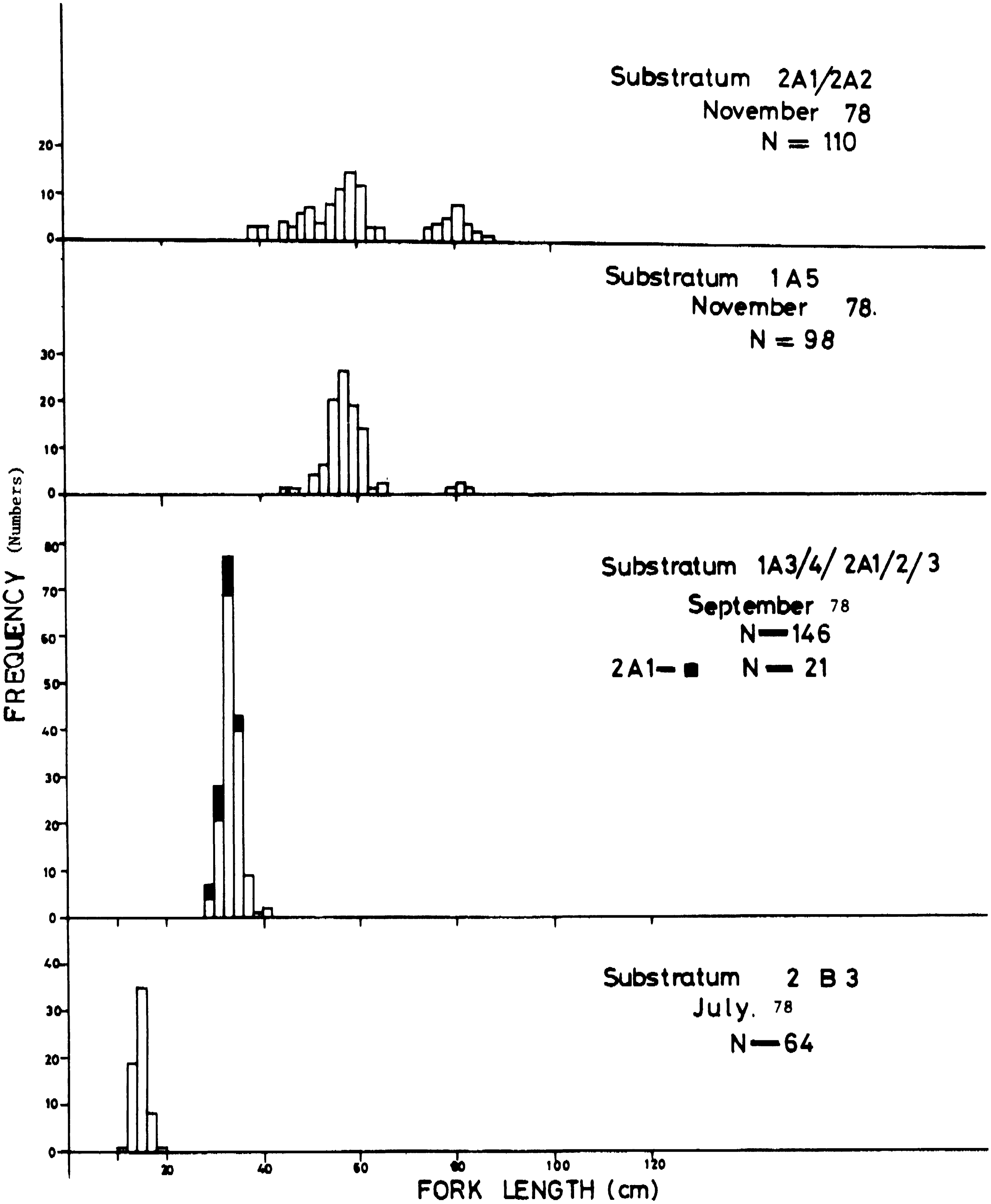


Fig. 5.3 - Length frequency distribution for <u>Scomberomorus commerson</u> in trawl catches (for stratum codes see report on demersal species, FAO, on press)

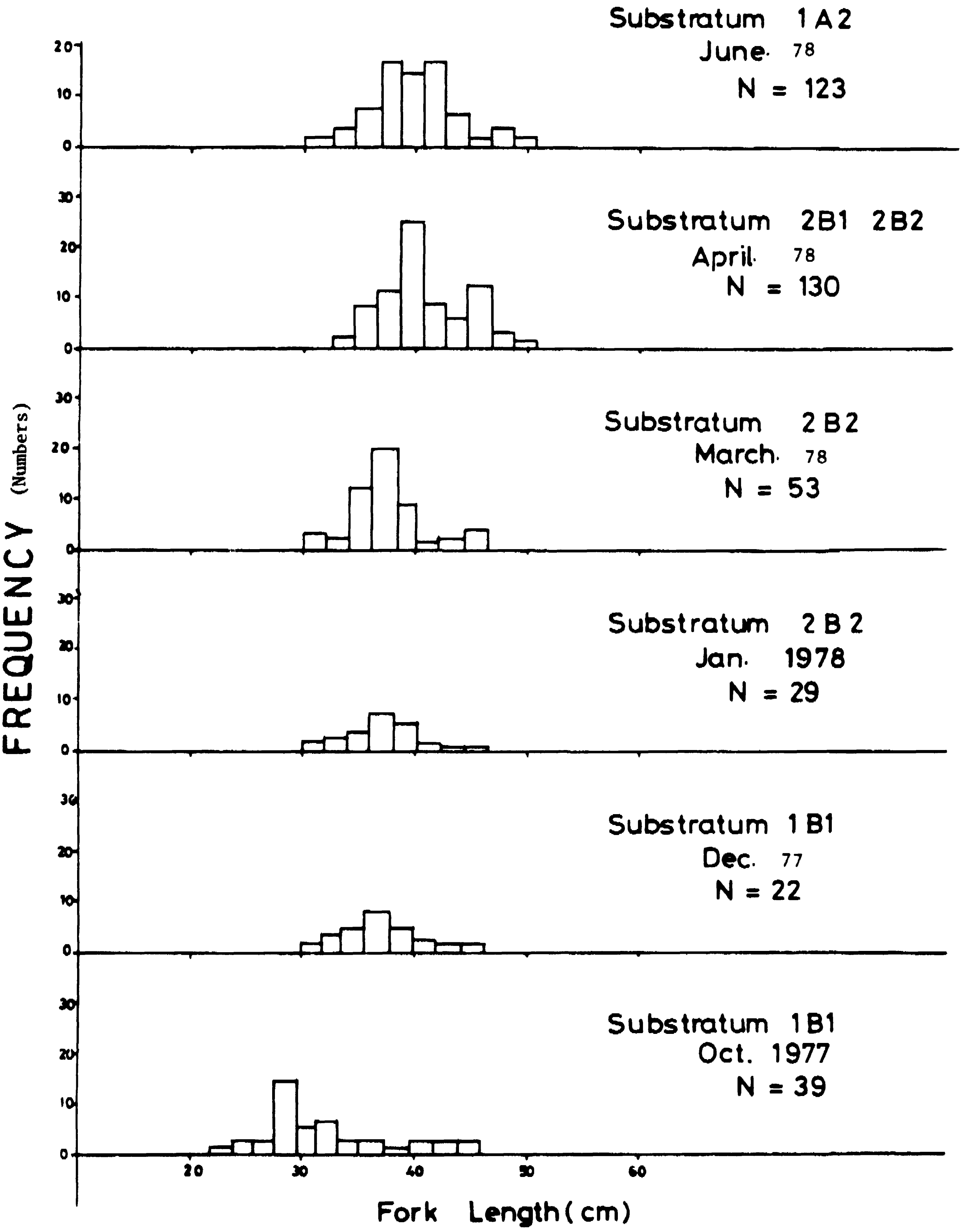


Fig. 5.4 - Length frequency distribution for <u>Scomberomorus guttatus</u> in the Gulf

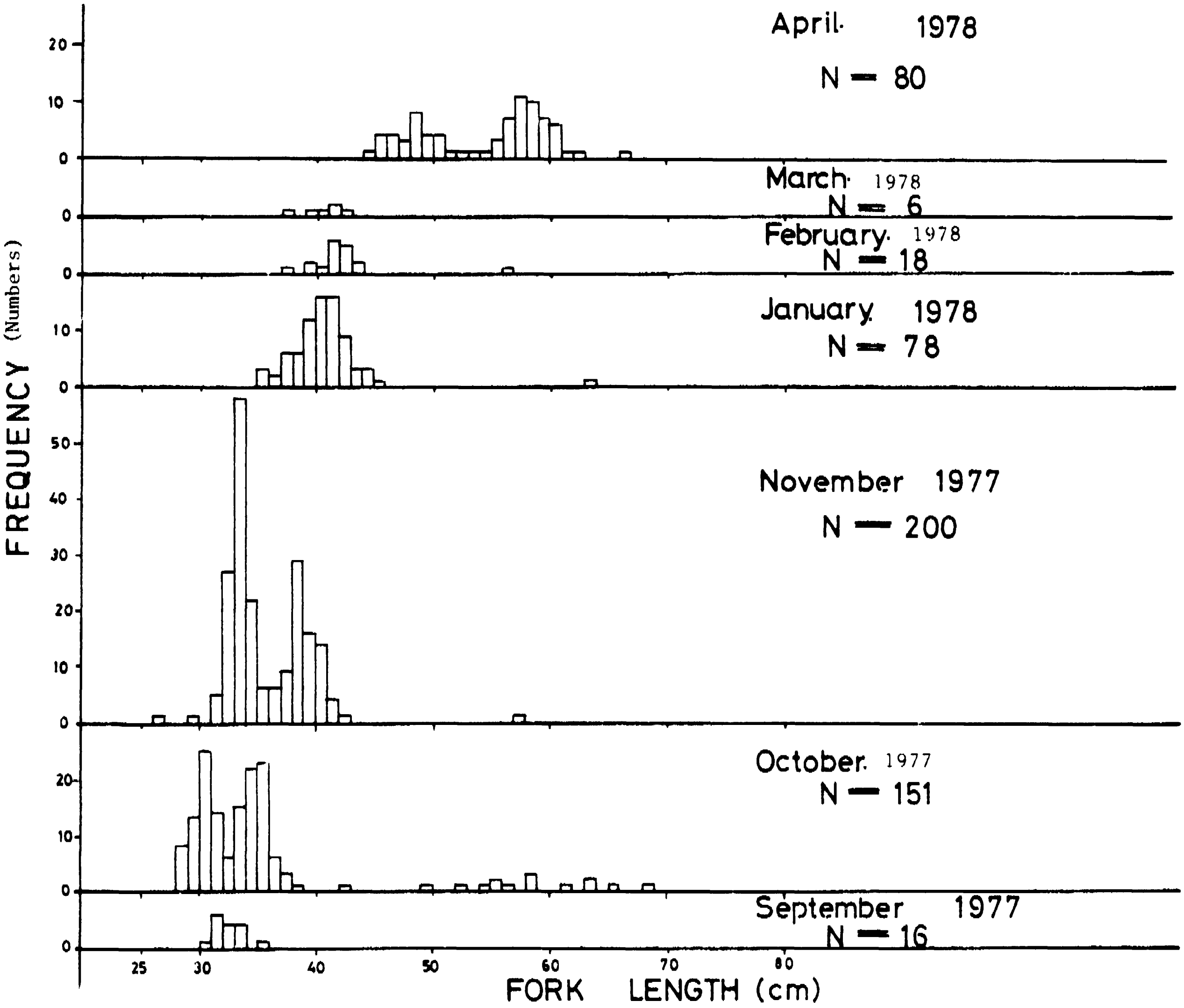


Fig. 5.5 - Length frequency distribution for _Euthynnus affinis_

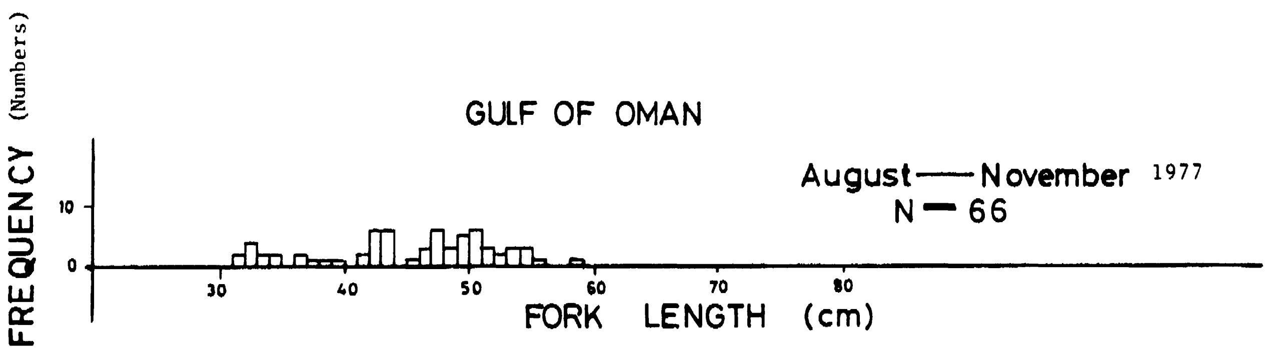


Fig. 5.6 - Length frequency distribution for _Thunnus tonggol_

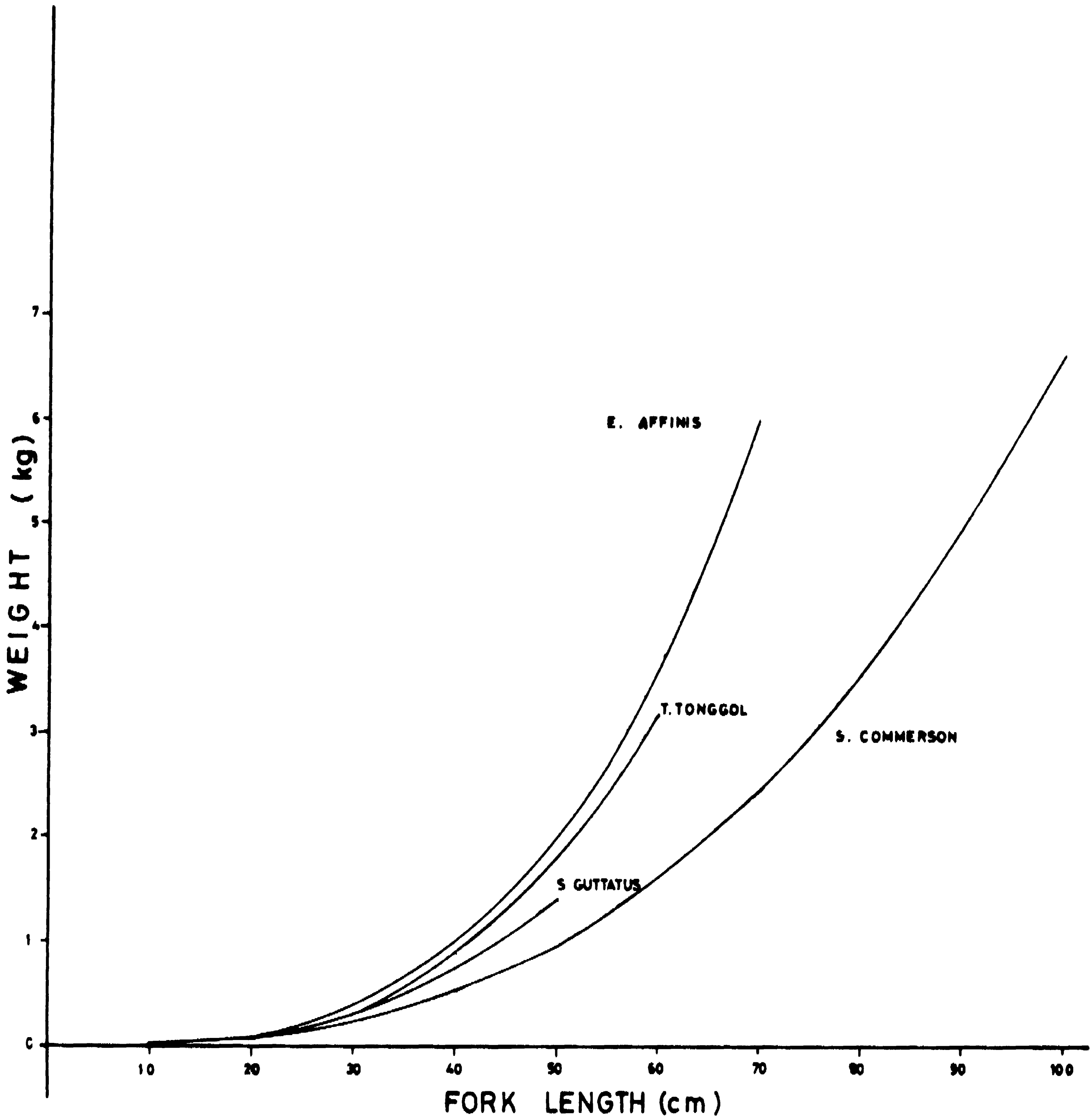


Fig. 5.7 - Length weight relationship for four species of Scombridae

6. GENERAL EVALUATION

6.1 EXISTING FISHERY FOR SMALL PELAGICS

The production of small pelagics by existing artisanal and large-scale fisheries in the project area is estimated to be approximately 10 000 t/yr. The scad, horse mackerels and Indian mackerels are the main species groups. Due to poor markets for sardines in most of the member countries, excluding Iran and Oman, little effort is specifically directed to this resource, and sardines caught by large trawlers are generally discarded at sea. There is a sardine canning plant in Bandar Abbas (Iran) but the exact quantity of raw material supplied by the traditional crafts in that area is not known. Between November 1976 and December 1977 purse seiners operating off Ras Al Khaimah produced about 5 000 t of sardine (see part 4). While sardines were the main object of this fishery, considerable quantities of scad and horse mackerels also entered the catch. Analyses of the results revealed that these small carangids were caught mainly between October and March and the catch rate for this group varied between 0 and 9 t/set. There are also reports of very large quantities of sardines and anchovy on the north coast of Oman in the past, but significant production of these species groups from that locality is not evident at present.

Therefore, on the basis of available information and the occasional sampling, the present level of production of small pelagics, in the various member countries, is roughly estimated as follows:

	t/yr
Iran	3 000 - 5 000
Iraq	100
Kuwait	650
Saudi Arabia	150
Bahrain	50
Qatar	100
UAE	250 1/
Oman	5 000
Total	9 300 - 11 000 t/yr

1/ The 5 000 t of sardine landed by Ras Al Khaimah Fishing Company in 1977 are not included here

The small Carangidae, which form the main component of the present landings of small pelagics, appear to be caught throughout the year. The sardines, on the other hand, seem to be mainly caught seasonally, except by Ras Al Khaimah fishery which showed year-round catches. In all cases the peak period appears to be the cooler months of the year. Efforts through gillnet, beach seine, cast net and encircling types of nets contribute to the production of sardines and anchovy, but large catches of small carangids are made by some artisanal fisheries and large trawlers.

6.2 INFORMATION FROM THE TRAWL SURVEY

During the demersal resources survey with bottom trawl gear, small pelagic species such as scads (Decapterus selar), horse mackerels (Trachurus) sardines (Sardinella dussumieria), ilishas (Ilisha), anchovy (Stolephorus) and indian mackerel (Rastrelliger) also entered the catches. Though the bottom trawl gear may not be the most efficient sampling gear for

these species, very significant catch rate values were obtained for some of them, particularly the small carangids, perhaps because of the high opening of the trawl net used (Engel's). Hence the data from this source were analysed for supplementing the results of the acoustic survey, on distribution and abundance of small pelagics. The small carangid species mentioned above formed nearly 12.6% of the trawl catches in the Gulf and 2.6% of those in the Gulf of Oman, while the figures for Clupeidae were 3.2% and 0.9% in the respective areas. The other groups were negligible.

The distribution of catch rates by substrata for these species groups are presented in the report on the demersal resources in the Gulf and Gulf of Oman (FAO, in press). The small carangids showed mean catch rates of 70.8 kg/h in Area 1, 85.5 kg/h in Area 2 and 19.4 kg/h in Area 3. Though catch rates of over 100 kg/h were observed in some substrata in all three areas, it was more in Area 2 than in the other two areas. In the Gulf of Oman, the concentration was found to be relatively poor and with better results on the Iranian side than the Arabian side. The catch rates for sardines were much lower. This group was caught mainly in the shallow waters on the Iranian side, off the northern part of Saudi Arabia, northeast of Qatar and near the Strait of Hormuz. In the Gulf of Oman the results were very poor. Indian mackerel catches were uniformly poor all over the survey area except for one or two sporadic patches, while the anchovy catches were almost nil all over the survey area excluding the substrata close to the northwestern end of Iran and the Shatt Al Arab.

The total biomass estimated for all these species groups in the whole project area, on the basis of the trawl catch rates, was approximately 168 000 t and the small carangids contributed almost 76 percent (FAO, in press).

6.3 INDICATIVE FISHING FOR SMALL PELAGIC SPECIES

Detailed report on this subject is included in Bjarnason's draft report "Large and small scale fishing vessels and methods" (unpublished mimeo). Results from day-time fishing in the southeastern part of the Gulf showed some degree of similarity to the species composition and catch rates observed in the results of the Ras Al Khaimah Fishing Company Operations. In the northwestern part of the Gulf and the Gulf of Oman, schools of small pelagic species were not frequently observed during the period February to May 1979, and day-time purse seining attempts were generally unsuccessful but night-time purse seining with light attraction in the northwestern part of the Gulf and the Gulf of Oman gave very encouraging results. Even when echo-traces of sardines showed extremely poor concentration, the use of surface and underwater lamps brought about heavy concentrations of sardines and mackerels, particularly when the vessel was allowed to drift with the lights on. The results were good mainly within the depth range of 17-30 m. It appears that the average catch per set with light attraction will be higher than that for day-time fishing on schools.

The catch composition from the indicative fishing showed that *Sardinella sindensis* was the predominant clupeid on the Arabian side of the Gulf, followed by round herring (*Etrumeus*) Whereas rainbow sardine (*Dussumieria*) and *Ilisha* appeared more frequently towards the northwestern end of the Gulf. Anchovies (*Stolephorus*) never appeared in any significant quantities in the catches were occasionally caught in small quantities in the northwestern part of the Gulf. Small carangids such as *Decapterus kiliche* frequently appeared in reasonable quantities.

6.4 RESOURCES OF SMALL PELAGIC SPECIES

Whereas a quantitative acoustic survey is the only available method to obtain a quick and relatively good estimation of the distribution and abundance of small pelagic species in an area for which little information is available, the proper interpretation of the results requires additional knowledge. First of all, the acoustic method does not give information on fish species and requires substantial additional fishing for identification of species and determination of species composition if more than one species of small pelagic fish occur. Such identification and determination of the proportion of each species is also essential for determining the conversion factors which depend on back-scattering strength of each species, required for converting relative estimates into absolute estimates of fish density. Even if these conditions are fulfilled, the behaviour of the fish, in particular vertical and horizontal migrations into and out of the surveyed water body, may greatly influence the estimates. Thus, a single survey only provides information on the situation in the surveyed area at that particular period of time and information on behaviour will be required for the interpretation of survey estimates and differences in estimates between surveys, in order to determine the real magnitude of the resource. Furthermore, the survey estimates as all estimates based on sampling, are subjected to sampling errors, which in some cases may have led to figures higher or lower than the real values.

It is considered likely that the seasonal variations observed (see part 3) are realistic in terms of the component of the stocks available within the area and column of water actually surveyed, and it is unlikely that the survey technique or subjective evaluation would have been entirely responsible for such high variation. Therefore, a combination of factors such as natural fluctuations in the stocks, behavioural characteristics such as spawning migration, vertical migration, schooling, etc., and sampling variations influenced by environmental conditions could have contributed to the observed variation. It should also be noted that during the acoustic survey small carangids have been clearly identified as a contributor to the biomass in September/October, but not so in other seasons. The demersal survey, on the other hand, has not only shown a higher biomass for this group than the pelagic survey, but also indicated higher trawl catch rates for this group in October/November in all depth strata in the Gulf. Further the demersal survey showed that this group is also well distributed in the deeper part (more than 50 m) of the southeastern Gulf. The influence of these results should be taken into consideration for the seasonal variation in the biomass, and the fact that this group will contribute significantly to the demersal trawl fishery should be borne in mind when making any economic evaluation.

The influence of environmental conditions on the distribution of small pelagics in the survey area, particularly within the Gulf, would contribute not only to a high seasonal variation but also to a high annual variation. This is evident from the fact that a larger number of schools was observed in winter 1977 than during the corresponding period in 1978, and this also could have contributed to the variations observed. During periods of "shamal" (predominantly northwesterly winds) small pelagics such as sardines were generally not in schools and they tend to disappear from surface layers. During such times the echo traces and bottom trawl hauls have shown that they were distributed very close to the bottom.

Though methods to determine confidence limits for biomass estimates from acoustic surveys have been developed elsewhere, these have not yet been applied in the present survey results. Sampling of the fish schools has, in many cases, been difficult due to fish behaviour and limitations of the fishing gear. The amount of sampling has therefore been rather limited and behaviour of fish is still largely unknown. Hence, in the present report all available information from all sources is considered together to arrive at the best possible evaluation of the survey results.

Estimation of the commercial catch rates for sardines by purse seining, both during day and night, and for small carangids by bottom trawling and purse seining, is possible from the indicative fishing and other information available. However, in the case of the anchovy such an estimation is not possible. In spite of the fact that the purse seine net used during the indicative fishing had a mesh size small enough (13 mm) for capturing this species catches were extremely poor both during day and night. Though an interpretation of the behaviour has been attempted on the basis of the acoustic survey results, it could not be confirmed by the indicative fishing. Further investigations are necessary to predict the behavioural pattern of this species in the project area and to consider effective means of exploiting this resource.

Lanternfish (Myctophidae) form a very considerable potential resource in the Gulf of Oman, and R/V DR FRIDTJOF NANSEN caught 2-4 t/h with midwater trawl. Commercial catch rates have to be determined for this resource also but the possibilities of utilizing this resource must be determined first.

In view of the fact that in the major part of the project area sardines tend to be sparsely distributed at various levels of the water column instead of being concentrated in schools, light attraction techniques may encourage commercial exploitation in a much large area than that which would be covered by vessels fishing only on well defined schools.

Potential yield by area may give different economically exploitable potential for a mixture of species. If there is only a single population for each of these groups, then exploitation in any one area could influence the total potential, but if independent populations exist in the project area then the potential will depend on the area exploited.

Whereas the average size of the school will basically determine the catch per set that could be realized in day-time purse seining, that for night-time is influenced by a number of other variables such as density of the sparsely distributed fish, duration of ligh attraction and the volume of water effectively illuminated. Effectiveness of the illuminati in turn depends on the intensity of the light used, turbidity of the water and the vessel's drift.

The results presented in this report are first estimates and hence to be used with caution. Determination of commercial catch rates for various methods of exploitation, monitoring surveys and systematic collection of catch and effort statistics are essential follow-up actions for future assessment of the status of the stocks and management of the resources.

6.5 RESOURCES OF THE LARGE PELAGIC SPECIES

The resource of this category of fishes is poor in relation to those of the small pelagic and demersal species in the project area. It includes, however, species which are commercially very valuable in the region, such as the king mackerel and other species which are highly valued elsewhere. The information collected is insufficient for evaluation of the potential for development.

Though schools were sighted on many occasions, quite often they could not be effectively caught and even the artisanal fishery does not appear to be exploiting these stocks efficiently because the gear in use seems to need considerable improvement, and varying demand for various species groups results in the effort being shifted seasonally

to and from the fishery for large pelagics. The seasonal trend observed in the artisanal fishery, and observations during the survey, seem to discourage a steady round-the-year application of fishing effort on this resource, except in certain localized places like the Strait of Hormuz or the eastern end of the Gulf of Oman.

The environmental condition within the Gulf seems to be less conducive than that of the Gulf of Oman for tunas like yellowfin, skipjack or even longtail tunas. But other Scombridae such as king mackerel, little tuna and frigate mackerel may find conditions inside the Gulf favourable during specific periods when water temperature salinity and oxygen levels are closer to those of the open sea. On the other hand, in the Gulf of Oman the conditions are very much similar to open seas, with neritic and oceanic provinces, and much less variation in temperature and salinity. It is interesting to note that the area between, and including, the Gulf of Aden and the Gulf of Oman seem to show relatively higher concentration of longtail tuna than any other area in the Indian Ocean, west of Malaysia and Australia.

There is considerable similarity in the seasonal variation in the availability of small and large pelagic species to the existing fisheries, and some of the small pelagics such as *Sardinella* spp., *Stolephorus* sp., *Decapterus* sp., *Caesio* sp., *Mene* sp., etc., are known to be suitable live bait for tuna and tuna-like fishes. Perhaps the live bait method could improve capture when schools of these fish are sighted but not effectively caught by existing methods. Exploratory fishing with tuna longlines will be required to determine whether deep-swimming tuna are present in the central deep part of the Gulf of Oman.

7. SUMMARY AND REFERENCES

7.1 SUMMARY

7.1.1 Resources of Small Pelagic Species

An acoustic survey for the resources of small pelagic species in the Gulf and Gulf of Oman was carried out between March 1977 and October 1978 by R/V LEMURU (FAO/UNDP) and R/V MAJID (UAE). For this survey the three statistical areas demarcated earlier for a demers survey,were adopted for the convenience of covering each statistical area in a single cruise. R/V LEMURU conducted a systematic acoustic survey along parallel tracks (20 n.mi apart) in the Gulf and along a sawtooth track in the Gulf of Oman. R/V MAJID mainly concentrated on scouting for schools and exploratory fishing for small and large pelagic species, particularly in areas directly east and west of UAE.

A preliminary phase in the acoustic survey to determine basic conditions and best survey design was carried out between March and August 1977. The main survey covered the project area three times; towards the end of the warm season (1977), during the cool season (1978) and again in the warm season (1978). Sampling was carried out with purse seine and midwater trawl. Special cruises for live fish calibration and day-night variation experiments were also conducted.

Sampling indicated that, true to tropical sea conditions, there was considerable mixing of species groups in most parts of the survey area. The main species groups identified were Sardinella spp. (sardines), Stolephorus spp. (anchovy) and small Carangidae (scads and horse mackerel). Other groups recorded were Dussumieria sp. (rainbow sardine), Ilisha sp. (ilishas). Etrumeus sp. (round herring), and Nematalosa sp. (gizzard shad). There was a large variation in the percentage species composition by area and season with noticeable differences between the Iranian and Arabian sides. The Arabian side of the southeastern Gulf showed a very high percentage of sardines. In the Gulf of Oman, mesopelagic lanternfish (Myctophidae) was the most predominant group.

Though sonar was used during the preliminary phase of the survey in order to determine number of schools, size of schools and ultimately the abundance, this system of investigation was discontinued during the main survey because of the limitations to the effective performance of the sonar, caused by strong thermal stratification occurring in the survey area, in particular during the warm season.

The density distribution based on transformed integrator readings are presented in the report. It was evident that small pelagics, particularly sardines, were mainly concentrated in areas less than 40 m deep. This however does not apply to small carangids which were found in high concentrations even in deeper waters. The small pelagics, such as sardines, may be distributed from bottom to surface in high and narrow schools during day-time and often near the surface at dawn and dusk. At night the schools were spread out into homogeneou layer of fish throughout the whole depth range. Behaviour of anchovies (Stolephorus sp.) was found to be unpredictable. Small carangids were caught with midwater trawl mainly at night and with bottom trawl in day-time, indicating their tendency to be distributed in the lower part of the swimming layer for pelagics, both in shallow and deeper waters of the Gulf.

In the Gulf of Oman, Myctophidae (lanternfish) were mainly distributed beyond the 150 m depth zone and appeared in two layers at 150-200 m and 250-300 m during the day, and in a singl layer around 10-50 m at night.

Sonar readings in the southeastern Gulf during May 1977 showed an average of 11 schools/ n.mi with the average height of a school being less than 6 m, the average depth of the school from the surface not exceeding 30 m and the diameter of a school generally under 40 m. A combination of the results from the survey and other sources indicated that in the southeastern part of the Gulf (Area 2) the sardine schools were generally under 10 t, rarely exceeding 30 t and the average size of a sardine school was between 2 and 3 t. In the northwestern Gulf and the Gulf of Oman the fish appeared to be more dispersed.

Biological information obtained during the survey was very limited, but some information on size composition, spawning season and sex ratios is given. There is no clear evidence of migration into or out of the survey area though there are indications of localized migrations between the Strait of Hormuz and the southeastern part of the Gulf.

The constants determined by regular instrument checking, live fish calibration and day-night variation experiments were used on relevant integrator readings to convert the relative density values into absolute densities and then into biomass. The large extent of the area and timespan for each coverage placed some limitations on the sampling conducted and hence the components of the estimated biomass for the various species groups indicates relative magnitudes rather than absolute abundance for each group.

For the small pelagics in the project area the main survey produced biomass estimates of 1.2 and 1.7 million t for the two warm season coverages and 250 000 t for the cool season. On the other hand the preliminary survey with sonar and integrator system gave a comparable biomass estimate of 600 000 t for the southeastern part of the Gulf.

The high seasonal variation was considered to have been contributed to by the cumulative effect of fluctuations in the stocks, behavioural characteristics of the species and sampling variations. One probably significant factor is the seasonal movement of small pelagics into and out of the very shallow area (less than 10 m deep) (43 000 km^2) in the Gulf which could not be surveyed due to inaccessibility. The estimated mean total biomass of 850 000 t of small pelagic fish was distributed as follows: 65% in the southeastern Gulf (Area 2 mainly on the Arabian side), 30% in the northeastern Gulf (Area 1) and only about 4% in the Gulf of Oman (Area 3).

The present level of production of small pelagics is not very high and is estimated to be roughly 10 000 t/yr, and consequently the potential yield was calculated assuming a virgin biomass status. In the absence of reliable estimates of mortality rates for the small pelagic species, the estimated potential yield values of 110 000 t for the northwestern Gulf, 250 000 t for the southeastern Gulf and 15 000 t for the Gulf of Oman, would serve as indicators of their order of magnitude. Of the total potential yield of about 400 000 t, nearly 60% would be sardines.

The biomass estimates for the mesopelagic fish (lanternfish) in the Gulf of Oman were 4.5, 2.8 and 1.7 million t for November (1977), May (1978) and September (1978), respectively (see part 3).

7.1.2 Resources of Large Pelagic Species

Scouting for surface schools and sampling with trolling lines and purse seine for identification of species and their general distribution trends, were carried out by R/V MAJID between August 1977 and August 1978. This was in addition to exploratory fishing

for small pelagics and the main areas covered were the waters east and west of UAE Scomberomorus commerson (narrow-barred king mackerel), S. guttatus (Indo-Pacific king mackerel), Thunnus tonggol (longtail tuna) and Euthynnus affinis (eastern little tuna) were the main large pelagic species observed while numerous other species of large Carangidae (rainbow runner and queenfish), Carcharhinidae (sharks), Coryphaenidae (yellowfin tuna) and Auxis thazard (frigate mackerel) have also been observed in the project area.

Longtail tuna was present mainly in the Gulf of Oman whereas eastern little tuna showed a wider distribution extending far into the Gulf. The king mackerels were distributed over practically the entire project area and formed the most predominant group. Of the two main species S. commerson was commonly found on the Arabian side while S. guttatus has been frequently observed on the Iranian side.

Availability of large pelagic species to the existing fisheries seemed to be mainly during the cooler months. An average of 9 and 2 schools per day were sighted on the western and eastern sides of UAE respectively during MAJID cruises. As much as 6 t of tuna and tuna-like fishes have been caught with a sardine purse seine in one set by a purse seiner from Ras Al Khaimah.

Some observations of the size composition, sex ratio and maturity are presented. On the basis of the available information, estimation of the potential yield for this group is not possible. The estimated level of present production is about 20 000 t/yr.

Given the present status of the fishery, efficiency of the methods used and the effort applied on this resource, it is conjectured that there are possibilities of increasing the production to almost twice the present level.

7.2 REFERENCES

Abbes, R. and H. Ferrugio, 1977 Analysis of the traditional fishing activities in Bushehr and Bandar Abbas. Bull.Sci.Tech.Mar.Fish.Res.Inst.Iran, (13) (in French and Farsi)

Alkholi, A.R. and B. Soloviov, 1978 Fisheries of Kuwait. Kuwait, Ministry of Public Works, Kuwait

Ben-Yami, M., 1975 Southern Red Sea fisheries. Limited development prospects - a personal view. World Fish., 24(5):94-5, 97-9

Bjarnason, B.A., 1979 Final draft report on large and small scale fishing vessels and methods. Regional fishery survey and development project RAB/71/278. Rome, FAO, pag. var. (mimeo)

FAO, 1976 Survey technique and strategy. Report of the Ad hoc working group on survey technique and strategy. Regional Fishery Survey and Development Project. Rome, FAO, FI:DP/REM/71/278/1: 45 p.

FAO, 1978 Final report. Survey results of DR FRIDTJOF NANSEN. Rome, FAO, Norway Funds-in-Trust, Indian Ocean Programme, IOFC/DEV/78/43.2:13-61

FAO, Demersal resources of the Gulf and Gulf of Oman. Regional fishery survey and development project RAB/71/278. Rome, FAO, DP:FI/RAB/71/278/10:122 (in press)

FAO, Environmental conditions in the Gulf and Gulf of Oman and their influence on the propagation of sound. Regional fishery survey and development project RAB/71/278. Rome, FAO, DP:FI/RAB/278/12 (in preparation)

FAO/ACMRR, 1978 FAO/ACMRR ad hoc group of experts on the facilitation of acoustic research in fisheries. Report of the meeting of the working party on fish target strength, Aberdeen, Scotland, 13-16 December 1977. Rome, FAO, ACMRR:9/78/Inf.14:27 p.

FAO/UN, 1967 Report to the Government of India on exploratory tuna longline fishery off the southwest coast of India. Based on the work of K. Kawaguchi, FAO/TA tuna fishing expert. Rep.FAO/UNDP(TA), (2274):47 p.

Fibiger, H. and K. Frederiksen, 1957 Report to the Government of Iran on exploratory fishery survey in Bandar Abbas region, 1955/56. Rep.FAO/ETAP, (646):36 p.

Forbes, S.T., 1978 Absolute estimates of fish target levels from live fish experiments. Paper submitted to the FAO/ACMRR ad hoc group of experts on the facilitation of acoustic research in fisheries, Aberdeen, Scotland, 13-16 December, 1977. Rome, FAO, ACMRR:9/78/ 10 p. (mimeo)

Gjøsaeter, J., 1978 Aspects of the distribution of the Myctophidae from the western and northern Arabian Sea. Rome, FAO, Norway Funds-in-Trust, Indian Ocean Programme, IOFC/DEV/78/43.2:62-108

Holt, S.J., 1960 A preliminary comparative study of the growth, maturity and mortality of sardines. In Proceedings of the World Scientific Meeting on the biology of sardines and related species, edited by H. Rosa Jr. and G. Murphy. Rome, FAO, vol.2:553-61

Hull, L.E., 1978 A summary of the present state of knowledge concerning the Saudi Arabian Gulf shrimp fishery with particular reference to the artisanal sector. Field Rep. White Fish Auth./Fish.Dev.Proj.Saudi Arabia, (24):13 p. (mimeo)

Johannesson, K.A. and G.F. Losse, 1977 Methodology of acoustic estimations of fish abundance in some UNDP/FAO resource survey projects. Rapp.P.-V.Réun.CIEM, 170:296-318

Kristjonsson, H., 1979 A study of the artisanal fisheries of Qatar and recommendations for improvements. Rome, FAO, RAB/71/278 (mimeograph)

Kristjonsson, H., 1979 Some aspects of small scale fisheries in Bahrain. Rome, FAO, RAB/71/278 (mimeograph)

Nair, R.V., 1960 Synopsis on the biology and fishery of the Indian sardines. In Proceedings of the World Scientific Meeting on the biology of sardines and related species, edited by H. Rosa Jr. and G. Murphy. Rome, FAO, vol.2:329-414

Olsen, S., 1969 A note on estimating school size from echo traces. FAO Fish.Rep., (78):37-48

Rostami, I.K., 1960 Biology and fishing of sardines of southern Iran. In Proceedings of the World Scientific Meeting on the biology of sardines and related species, edited by H. Rosa Jr. and G. Murphy. Rome, FAO, vol.3:1213-20

Smith, P.E., The horizontal dimensions and abundance of fish schools in the upper mixed layer as measured by sonar. In Proceedings of the International Symposium on Biological Sound Scattering in the Ocean, edited by G.B. Farquhar. Washington, D.C., Navy Center for Ocean Science, pp. 563-91

Thomas, D., Study of existing fishing gears and methods in artisanal fishery of the United Arab Emirates and suggested improvements. Rome, FAO, RAB/71/278 (mimeograph)

Thomas, D., Study of existing gears and methods in artisanal fishery of Bahrain and suggested improvements. Rome, FAO, RAB/71/278 (mimeograph)

Vidal-Jünemann, J. and K.A. Johannesson, Résultats d'une campagne de prospection acoustique:
1976 abondance et distribution des ressources en poisson pélagiques dans les eaux algériennes. Rapport préparé pour le projet de développement des pêches. Rome, FAO, FI:DP/ALG/72/003/1:41 p.

Wheeler, J.F.G. and F.D. Ommanney, Report on the Mauritius and Seychelles fisheries survey,
1953 1948-49. Fish.Publ.Colon.Off., 3:120-45

White, A.W. and M.A. Barwani, Survey of the Trucial States Fishery resources with reference
n.d. to Sultanate of Oman 1969/71. Trucial State's Council. Dubai, National Printing Press, 140 p.